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THE BUCEROTIDÆ, OR HORNBILLS.

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(With a Coloured Plate.)

The Zoological Society having recently obtained a living specimen of an adult female hornbill (*Hydrocissa convexa*) from Borneo, furnishes us with the occasion to give some account of these curious birds, which are very seldom to be seen alive in Europe, and are even considered great curiosities by residents in the countries they inhabit.

The hornbills are large and clumsy birds, seldom adorned with bright-coloured plumage, but in many cases bearing a really prodigious bill. In this respect they somewhat resemble the toucans, with which they are often confounded, though they have in fact little or no affinity or true relationship with them. While the toucans are strictly confined to the tropical parts of America, the hornbills inhabit the tropics of the Old World, being found in Africa, India, and the Indian islands. It is in this latter region that the greatest number of large and remarkable species are to be found; and having had frequent opportunities of observing them in their native haunts, I shall endeavour to give a correct idea of their form and habits in the Malay Archipelago, to which will be added a few words on their relationship to other birds and on their geographical distribution.

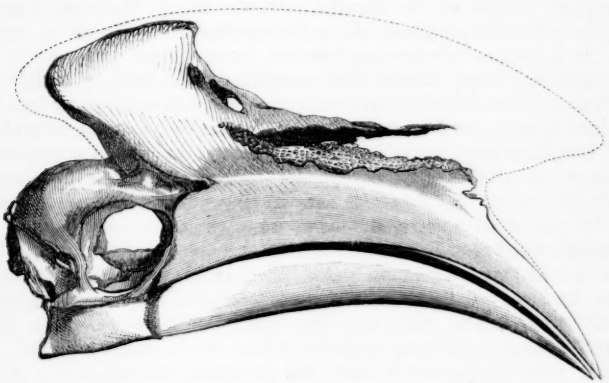
Form and Structure.—Hornbills are generally characterised by large and heavy bodies, rather long and powerful wings, very short legs, long neck and tail, and enormous bill. The plumage in all the larger species has a ground colour of black, sometimes tinged with bronze, and the tail and lower parts more or less varied with white. The neck is very often of a reddish-brown colour; the plumage is generally loose, and on the head and neck often approaches hair in its appearance. In some species the cheeks and a part of the neck is bare, and

adorned with brilliant colours. One of this kind, the *Buceros cassidix*, is figured in our plate. The feet are very remarkable, the three toes in front being joined together for some distance from the base, so that they cannot be spread open as in most birds, but form a broad sole to the foot, indicating that the feet are used merely to rest on, and very little for progression. They resemble on a very large scale the feet of a kingfisher, which, as every one knows, rarely or never hops, contenting himself with sitting still, and using his wings when he wants to move.

But the most remarkable feature of the hornbill is that from which they take their name—the bill. The form of this organ varies in every species, varies often in the sexes of the same species, varies even in the same bird from youth to age; yet there is a certain characteristic form, of which all the others seem to be modifications. It is always considerably curved, rather broad and angular at the junction of the two mandibles, and compressed above and below, generally forming a sharp keel along the top. This is the shape in many of the small African and Indian species, forming the genus *Tockus* of naturalists. Other species have the keel raised at the base of the bill, or have ridges on the sides which meet and form rings or crests at the top. In others again the keel is much elevated, swollen, and projecting in a point above the bill itself, till in the larger and more remarkable species a large boss or recurved horn rises up above the crown of the head almost as large as the true bill itself. In some of the African hornbills a curious modification occurs, in a sort of tube or cylinder open at the front, on the top of the bill. In those species which bear ridges on the sides or top of the bill the number of these is supposed to indicate the age of the bird; whence all hornbills are called by the Dutch in the east, and after them by the Malays, "Year-birds." In the *Buceros ruficollis*, figured in our plate, this rule will most likely apply at least for the first seven or eight years, as the young birds have no ridges, and others are found with all intermediate numbers up to about nine, after which the end ridges seem to scale away and become indistinct, so that it is not improbable the bird may live much longer than this would seem to indicate. In the great rhinoceros hornbill (*Buceros rhinoceros* of Linnæus) the bill attains perhaps its greatest size and beauty, the rich hues of orange crimson and ivory white with which it is adorned in the living bird being scarcely capable of imitation. It is this bird which excited the wonder of the early voyagers to Ceylon (where a variety of it exists), who believed it to have two heads—a statement which was long credited in Europe, and which may serve to teach us that the wildest and most improbable fictions of

early ages had probably a foundation in some curious natural phenomenon.

In this immense mouth is situated a very small tongue, so small and capable of so little motion that it may almost be considered rudimentary, and resembling much the tongue of a kingfisher. The bill itself is very light for its size, though containing a tolerably compact core of porous bone to its very extremity. The horn, however, adds scarcely anything to the weight of the bill, being completely hollow, except at the base,



SCULL OF HYDROCISSA CONVEXA (MALE).
(*The dotted line shows the outline of the bill.*)

where it has a bony core. The rest is merely an expansion of the thin horny sheath of the bill. Another remarkable peculiarity is that the upper and lower mandibles seldom meet, except at the base and tip, all the middle portion gaping from an eighth to a quarter of an inch apart. The only use of this anomalous structure which I can conjecture is that it enables the birds to carry a considerable quantity of fruit in the closed bill (the roof of both upper and lower mandibles being hollow), without crushing it, as they would be likely to do during the exertion of flying if they were obliged to hold the fruit by the pressure of the partly separated mandibles. This would render probable the truth of the singular fact stated by the Rev. J. Mason in his work on the "Natural Productions of Burmah," and probably communicated to him by the natives, that when the female of *Buceros bicornis* is sitting on its nest (in the manner to be presently described), the male brings her a continual supply of fruit; "but all must be unbroken, for if a fig or any other fruit is injured, she will not touch it."

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A striking peculiarity of some of the Indian hornbills is, the remarkable difference between the two sexes. In birds generally the bill is a very constant organ, and its slightest modifications are often characteristic of distinct genera. The sexes of many birds differ much in plumage, while the bill remains almost always the same. Here, however, the principal differences between the male and female bird are in the bills, the plumage remaining unchanged, or only offering differences in the colours of the head and neck. For example, the *Buceros ruficollis* (see plate) has the neck rich brown in the male, but entirely black in the female. In the black Malayan hornbill (*Hydrocissa Malayana*) the male has the bill pure white, with a very high keel projecting forward in an acute edge, while the female has it jet black, with a much lower keel of a different shape. These birds have of course been described as two distinct species, and are still thought to be so by some naturalists. I had, however, myself the good fortune to shoot a number of them on the same tree, all the black-billed ones proving by dissection to be females, and all the white-billed ones males. The young of both sexes have the bill white, and I have one female specimen in which some of the white of the young bird is left in patches on the black bill. In the species now living in the Zoological Gardens (represented in the upper figure of our plate), the male has the bill of quite a different shape and colour, and may well be taken for a different bird. In the very young birds the bill is quite simple, without any sign of the horns—in some cases resembling that of a young kingfisher, in others that of the small hornbills with a simple curved bill.

Habits of the Hornbills.—Considered as a whole the hornbills seem to be omnivorous, but the Malayan and Indian species are almost always fruit eaters, and I believe all of them prefer that kind of food when it can be obtained. They are seldom to be seen in cultivated districts, inhabiting almost exclusively the primeval forests, where the smaller species are often to be met with in flocks of a dozen or twenty, while the larger ones generally go in pairs. They fly very high, far above the tops of the loftiest trees, with neck stretched out and head bent downwards, progressing rapidly with powerful strokes of the wings, and accompanied by a sound which can be heard at a great distance. The noise produced during flight is in fact so loud and peculiar, that many persons cannot believe it to be produced merely by the mechanical action of the wings on the air. It may sometimes be heard a mile off, and as one of the larger species rushes by overhead it forcibly recalls the old legends of griffins and dragons, the awful sound of whose wings struck terror and dismay into the inhabitants of the country

they came to devastate. The sound which it seems to me most nearly to resemble is, the puffing of a locomotive when starting with a heavy train. There is only one other bird that I have heard produce a sound with its wings at all resembling (though not quite equalling) that of the great hornbills. It is the Muscovy duck (*Cairina moschata*) in its native country, South America. Both these birds have a very heavy body; both have, comparatively speaking, a small area of wing, and must, therefore, to support themselves, beat the air with immense force.

The rhinoceros hornbill sometimes exceeds four feet in length, and exhibits the greatest size reached in the Passerine order of birds. The exertion of flying is so great that it generally rests at intervals of about a mile on some very lofty tree, whence after a few minutes it resumes its flight. In some of the interior villages of Sumatra and Borneo, where a gun is never heard, they will settle upon and even build in trees in the village itself; but in more populous districts, where guns and Europeans abound, they are very shy, and take flight on seeing a man even at a considerable distance.

It is interesting to watch their motions when settled upon a fruit tree. Their weight is so great that they cannot venture out on the smaller branches, nor can they cling to the twigs, or flutter among the foliage like smaller fruit-eating birds. They cannot even hop readily from branch to branch, their short legs only serving to support the massive body. On first alighting they look cautiously round till they discover some spray of fruit hanging within reach of the branch they are upon, when they move sideways towards it by a sort of shuffling hop; and then stretching out their long neck, seize a fruit by the extreme point of the bill. To swallow it now they have got it, is however, no such easy matter; for the tongue not being adapted for deglutition they are obliged to jerk down every mouthful by suddenly throwing back the head, and at the same time opening the bill, by which action the fruit is of course thrown down the throat. This habit has given rise to the statement that this bird as well as the toucan throws its food up in the air before eating it; but a careful observation of the birds feeding in a state of nature, proves that the fruit never leaves the point of the bill except to be jerked down the throat. The action, however, so much resembles that of catching something in the mouth, that the mistake is easily accounted for. Having finished all the fruit within reach of one branch the bird with much deliberation takes flight to the opposite side of the tree, where the same operation is repeated till all the fruit that can be easily reached is exhausted. This is of course soon done, and it therefore happens that hornbills seldom visit a fruit tree more than two or three days consecutively; whereas pigeons,

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barbets, bulbuhls, and other fruit-eating birds may be found on the same tree daily for as many weeks. The discovery of a dinner every day in the year must doubtless be sometimes a matter of difficulty to the larger hornbills, and they are often obliged to resort to other kinds of food. From the gullet of the *Buceros cassidix* I have taken the fragments of large long-horned beetles (*Batocera*), and when residing in the forests of Celebes I once had an opportunity of observing from the door of my hut one of these insects captured, beaten repeatedly against the branch, and then swallowed. On another occasion I shot a Moluccan hornbill (*Buceros ruficollis*), to the roof of whose beak was sticking a large lump of bees' comb, showing that he had been making a meal off bees' brood and honey. They are also positively declared by the natives to eat eggs and young birds occasionally. Yet notwithstanding this varied bill of fare there seems little doubt but that periodical scarcity of food is the most efficient check to their increase, as shown by the fact that the larger kinds are always scarce even where the smaller ones abound.

Most of the hornbills make their nests in hollow trees, though some of the African species are said to build rude exposed nests on lofty branches. The larger kinds lay only two eggs, the smaller ones probably a larger number, but all of a white colour. A remarkable habit has been recorded of at least three species, which, like so many of the strange facts in nature, was for a long time considered to be fable. As soon as the female has deposited her eggs the male imprisons her in the tree by closing up the entrance with clay and gummy substances, leaving only a small hole, out of which she puts the tip of her bill to receive the fruits with which he keeps her well supplied. She is kept shut up in this manner, some say, till the young are hatched, others till they are fledged. In the interior of Sumatra in January, 1862, one of my hunters brought me a male concave hornbill (*Buceros bicornis*), which he told me he had shot when in the act of feeding its mate. On going with him to the spot I saw a hole in the trunk of a large tree about twenty feet from the ground, out of which the bill of a hornbill was partially protruding. With great difficulty I persuaded some natives to climb up the tree and bring me the bird, which they did alive; and along with it a young one, apparently not many days old, and a most remarkable object. It was about the size of a half-grown duckling, but so flabby and semi-transparent as to resemble a bladder of jelly, furnished with head, legs, and rudimentary wings, but with not a sign of a feather, except a few lines of points indicating where they would come. A smaller species, inhabiting India and Ceylon (*Buceros monoceros*), is said by Mr. Layard to have a

similar habit. A third species found in Java (*Buceros plicatus*), very similar to the *Buceros ruficollis* of our plate, is said by Dr. Horsfield to be called by the natives "the jealous bird," from its extreme watchfulness over its partner. They assert that if any traces appear of the nest having been visited during the absence of the male bird he will on his return completely close up the opening with mud, and leave his unhappy wife and children to perish.

The voice of these birds is very harsh and grating. It is heard occasionally while they are flying, and also when they are alarmed. When, however, a bird is wounded or captured alive, the horrible noise it makes is perhaps not to be surpassed in the animal world. It is something between a bray and the shriek of a locomotive, and is kept up continuously, so as to be absolutely unbearable. When the female bird I have mentioned was captured on the nest we heard it about a mile off, a horrible noise even at that distance, and the screams continued without ceasing till it reached our boat. It is thought by some persons that the hollow protuberance of the bill may have something to do with the production of such a volume of sound, but besides that there is no communication whatever between the bill and the windpipe, the very large and strongly ringed trachea seems sufficient alone to produce it, especially when we consider the wonderful power and variety of the notes which proceed from the same organ in some of our small singing birds.

Classification.—The relations of the hornbills to other birds are rather obscure. Their large bills and general habits having much similarity to those of the toucans, they have been classed by some authors as the eastern form of that family. A careful comparison, however, shows that this resemblance is only superficial. The toucans have long and powerful legs, and can hop readily and actively about the trees on which they are feeding; but their wings are very small and weak, and their powers of flight are so feeble that in flying across the Amazon, which is three miles wide, they not unfrequently fall into the water from exhaustion. In the hornbills the reverse is the case, the legs being organs of support merely, and the wings the only means of motion. In the toucan's foot the toes are widely separated, the outer one being turned backwards, whereas in the hornbill the three anterior toes are closely joined together. The bill of toucans has no bony core and the tongue is excessively long, by both which characters it is widely removed from the hornbills. The internal structure shows this difference even more clearly, for the sternum or breast bone, which always has a general similarity of form in allied birds, is in this case as different as it well can be in two birds of the same order.

Other authors have placed them near the crows, on account of their conical bill and the semi-terrestrial habits of some of the African species, but almost every detail of structure is equally against this arrangement. The fact seems to be that they are a very peculiar and isolated group, with no immediate relations with any other birds. If we accept the general principle that all apparent isolations in nature are the result of the extinction of intermediate links which have once existed, we must suppose the hornbills, as we see them now, to be but a fragment of a great group of birds, containing many hundreds of genera and species, which once inhabited the great tropical continent, which there are indications of having occupied at a former geological epoch what is now the Indian ocean. Some of these birds would probably have filled up the gap that now exists between the hornbills and the other fissirostral birds, such as the kinghunters (*Dacelo*) of the east, and the puff birds (*Capitonidæ*) of America; for it is to some of these birds, though so much smaller and apparently so different, that the form of the feet, the structure of the skeleton, the shape of the bill in the embryo, and the character of the egg, show the hornbills to be really allied.

As in other families, which seem to be but the surviving remnant of much more extensive groups, there are among the hornbills some peculiar genera which differ much from all the rest. One is a rare Malayan species, the helmeted hornbill (*Buceroturus galeatus*), which, besides having two immense long streaming feathers in its tail, has a short straight pointed bill, with an immense hump on the top of it, which, instead of being hollow and light as in all the other species, is a solid bony mass of such density that the species has received a Malay name signifying "ivory bird." The habits of this rare and curious bird are unknown. The other anomalous form consists of the African genus *Bucorvus*, which has long legs, and habitually runs on the ground, where a true eastern hornbill never ventures. These birds are said to feed on insects, on small reptiles, and also on carrion, taking upon themselves something of the habits and outward appearance of vultures.

Geographical Distribution.—About forty-two species of hornbills are now known, of which eighteen or nineteen occur in Africa, nine or ten in tropical Asia, and seventeen or eighteen in the Malay Archipelago; a few of these being reckoned twice over as they occur on the borders of two of the districts, which however are, on the whole, inhabited by quite distinct species. In Africa they are found in all the country south of the Sahara, the smaller species being more abundant on the West Coast, while the larger semi-terrestrial species inhabit the more arid eastern districts. One or two of the smaller Asiatic species are

found in the mountainous forest country of Nepal, another seems confined to Ceylon; of the others some are confined to the Peninsula, others to Eastern India. How far they extend eastwards into Burmah or China is not at present known; but it is probable they will be found as far as the great forests extend in that direction, and from those regions it seems most probable we may yet receive some additional new species.

In the Malayan Archipelago the species are more numerous in the great islands of Java, Sumatra, and Borneo, in which twelve different sorts occur, ten of which are found in Sumatra, a smaller number in Borneo, and only three or four in Java, one of which is peculiar to it. In the islands farther eastward the species have a more restricted range, two very distinct kinds inhabiting Celebes, and being found nowhere else (the head of one of these, *Buceros cassidix*, is figured in our plate). Three are peculiar to the Philippine Islands, and one (*Buceros ruficollis*), of which the head is also figured, is found in almost every island of the Moluccas, in New Guinea, and in New Ireland, where the eastern range of these birds appears to terminate. They are quite unknown in Australia, and in the Archipelago, the islands of Timor, Flores, Sumbawa, Lombock, and Bouru do not possess them.

These facts agree very well with the supposition before made, that the hornbills were once more numerous and varied, and inhabited a now submerged continent, whence during the slow progress of geographical changes they have spread themselves to the surrounding countries. There is a great deal of independent evidence to show that the islands of Sumatra, Java, and Borneo were at no very distant epoch united with each other and with the continent of Asia, and we therefore find many of the species ranging over all these islands as well as some portion of the adjacent continent; while the islands further eastward, which have remained isolated for a much longer period, contain species which are peculiar to them.

The geographical distribution of the hornbills seems therefore quite in accordance with the almost universal belief of modern naturalists, that the present position of every living thing upon the earth is the result of that long and complicated series of geological changes and organic modification which the globe has ever been and still is undergoing.

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DARTMOOR AND THE DART.

BY PHILIP HENRY GOSSE, F.R.S.

NEAR the middle of July, having a little boy just recovering from hooping cough, for whom change of air was recommended, I determined to take him to Dartmoor. There was much in the historic associations of that seat of ancient civilization, that region where Britons mined and smelted tin and copper, and where Syrian and Sidonian merchants met, and chaffered, and displayed the precious things of Asia, ages before Rome was born—much in this, I say, that had a strange fascination for me; and, besides this, it was a peculiar tract of country, where I expected to meet with unwonted forms of life, interesting to both of us. Accordingly my boy took his butterfly-net and insect-boxes, and I a vasculum for ferns.

It was in cheery mood, then, that we set out from Marychurch on that brilliant July morning. The long trailing twigs of the wild clematis were spreading in profuse and elegant freedom over the hedges and rocky slopes of the Teignmouth road, and hanging nearly to the horse's feet; and the dark and glossy leaves of the beeches almost intermingled as the long pendulous and patulous branches met overhead, as we turned off towards Hele. The fetid iris, a plant so rare generally, so common here, showed its pale violet blossoms, in contrast with the crimson stars of the rose-campion; and all along the lower level of the banks shone clusters of the sweet germander speedwell, always charming in its bright azure hue, and here, most poetically, named by the peasantry, "angels' eyes." Groups of tall foxgloves rose from out of the rank herbage, and high up in the hedges there was a constant succession of dog-roses and honeysuckles, adorned with numbers of the elegantly-banded hedge snails, on the scout for their dewy breakfast, and looking like fantastically painted fruits clinging to the twigs.

Through Newton Abbot we roll, and remark with surprise how fast it is increasing on every side. On towards Ashburton, the scenery becoming richer and more varied. It is market-day at Newton, and numbers of farmers' daughters and wives—comely Devonian dames—are riding to market with cloth-covered panniers attached to their side-saddles—well filled, doubtless, with butter and eggs, poultry ware, or whatever mysteries besides Dame Dobbins is wont to carry on such occasions. The hedgerows are still gay with flowers; the abundant yellow vetchling, two species of St. John's wort, the toadflax, precursor of autumn, and hawkweeds, supply the

golden colours; the foxglove and the campions the crimsons; and the blues and purples are afforded by the profusely elegant racemes of the tufted vetch, resembling pendent clusters of grapes in miniature. We miss the polystichum, our most common hedge-fern, and instead of it the filix-mas spreads its great crowns along the road-margin, and the tall brake crowds up among the tree-trunks of yonder wood.

Peeps of the Moor, at least its south-west corner, break upon us at various turns of the road, blue and shadowy, like a huge rampart, ever becoming, as we advance, more and more palpable. At length we enter Ashburton, between lofty walls, grey, weather-worn, and lichened. Old, old walls are these; for the crevices of the courses are thickly studded with dense tufts of the familiar wall spleenwort fern*; so thickly, that viewed at a slight angle the whole surface of the upper wall seems covered with the feathery fringe. The plants have the appearance of great age; they are very luxuriant, but this is the result of their long growth, for when examined they have a very different character from the long and broad-leafed succulent crowns that adorn the hedges at Daccombe. These are narrow, thin, dry and wiry, and far more plumose, and of a golden-brown tint of green. The great snapdragon also throws out its crimson spikes from the walls.

Here, then, in this quiet old-fashioned place, one of the four ancient Stannary towns, and boasting the honour of having given birth to Gifford, the quondam editor of the *Quarterly*, we took up our head-quarters.

One of our earliest walks was to the romantic Dart at Holne Bridge. Leaving the town by the opposite end of the long street to that by which we had entered it, we found the walls again clad with the *trichomanes*, if possible even more luxuriant, and accompanied with other ferns, as the wall-rue, the common polypody, the ceterach, the maidenhair spleenwort, and the hart's tongue,—all, except the last two, particularly fine. Indeed, we cannot walk a mile without perceiving how pre-eminently this is a region of ferns.

It was a pleasant excursion, that early morning walk, with the brilliant sun drinking up the dewdrops, and the lark singing overhead, recalling Shakspeare's beautiful fancy:—

> "Hark! hark! the lark at heaven's gate sings,
> And Phœbus 'gins arise,
> His steeds to water at those springs
> On chaliced flowers that lies;
> And winking Marybuds begin
> To ope their golden eyes."

* *Asplenium trichomanes.*

As soon as we are well clear of the houses, as if the curtain of a stage had risen, we open in an instant a magnificent panorama. The country to the south and west stretches up in lovely slopes, mapped out in parti-coloured fields to the sky-bounded summits of the hills, divided by hedgerows and hedgerow elms, with cottages nestling in the bottom, whence the brawling of the little Yeo comes to the ear, as it hastens on to join the Dart. We trace the receding valley on towards Buckfast Leigh, and far beyond in the same direction Brent Beacon, a fine purple cone, towers above the general level. The voices of haymakers taking advantage of the promising day, and the sweet odour of the turned hay, tell what is going on behind these impervious hedges of hazel and beech. Before us the dim grey tableland of the moor, or at least the south-west tail of it, lies under the softening haze of the morning.

On the right the rugged rock shuts out the prospect, for the road has been scarped out of the living shale, but the ever growing shrubs and their gnarled roots, with creeping and trailing plants, conceal the rough stone with a graceful drapery. Half hid by a pendent curtain of ivy, we noticed a shallow cavity—I can scarcely call it a cavern—in which was growing a clump of navelwort,* of more than usual luxuriance even for these Devonshire lanes. The leaves, stalk, and flowers, were all most succulent, not a blossom faded. One of these flower stalks, out of a clustered group, I measured; it was half an inch in diameter, and exactly thirty inches in length from root to point.

A little further on, from the same rocky barrier, a spring gushes out breast high, and is received into a stone coffer, like the new drinking fountains of London streets, the water as clear and cool as a thirsty pedestrian could desire; nor was our relish of it diminished by the fact that we found in its clear recesses other revellers†—thorough teetotallers all.

Presently a rushing brook passes beneath the road, and, being collected into a wooden channel, crossed with great flags for gangways, hurries away to a clacking mill. It was pretty to mark the dense subaqueous forest of water-blinks, how its long tufts waved and quivered in the black rapid stream, beneath the shadow of the tall meadow-sweet, most delightfully fragrant, that profusely bordered the water. This, however, was a deviation through inadvertence; recovering the road by a cross lane, we found the columbine growing luxuriantly, said to be most elegant with its tall blue blossoms, but now out of flower; and the tutsan, the finest and rarest of our truly native

* *Cotyledon umbilicus.*

† *Gammarus fluviatilis, Ancylus fluviatilis, Limnæus pereger, Helix rufescens.*

St. John's worts. The beautiful spotted bastard-balm,* rarer still, was also here in full bloom, spangling the hedge with its large white flowers, blotched with purple on the lip. This is probably the identical spot in which it was found by Smith, who gives as its locality "a mile from Ashburton, on the road towards Plymouth."—(*Engl. Bot.*)

Now we are in the valley of the Dart; and those hills that slope upward on our left, so densely covered with dark timber, making a noble appearance, are the Hembury woods, on the other side of the river. A little farther, and the whispering sound of running water is heard, which momentarily increases in fulness. We know it is the Dart; but the bank of the road is high, and curbs the prospect. Here is a gap in the hedge; we look over into a dark glen, shadowed by tall trees, and crowded with foxglove; yonder is a bottom of deeper green-wood obscurity, whence the denser beech woods rise on the opposite hill. There is the seat of the sounding stream, but we see it not. A few yards more, and we climb over into the solemn grove: the whisper has become a roar, and there sweeps the lovely river. Just where we have struck it, a ridge of broken rock crosses its bed; above this, there is a glassy expanse, mirroring the trunks of the bordering trees and the black shadow; below, a broken foamy torrent: there is a short but pretty plunge over the dividing ridge, with a deafening noise, that combines the whisper with the roar. The views upward and downward are both beautiful; the latter specially, where the tall overspreading trees—*patulæ fagi*—shadow the whitening current in a long receding vista.

I was struck with the resemblance borne by the bank of the stream to the sea shore; the shale crops out, and this is worn by the rushing flood into smoothed, but irregularly angular, projections and hollows, exactly like tide-pools, while the sand lying here and there, washed into ripples, increases the *vraisemblance*. Nor was the illusion altogether dispelled by the vegetation; for the *Osmunda regalis*—the royal flowering-fern—which grows all along the very water's edge, presented a strange likeness to a sun-dried sea-weed, for the clumps growing on the points of the shale, and out of the sand, had formed great compact masses of black wiry roots, from which in many cases almost all the soil had been washed away, and which threw up only a few stunted and deformed fronds, in no adequate proportion to the size of the root-masses.

A tiny brook comes down the left bank, and pours its little cascade into the stream, and just here we find some fine tufts of the hard-fern,† growing out of the sand. It is a fern which

* *Melittis grandiflora.* † *Blechnum spicant.*

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we do not know around Torquay, but we became subsequently familiar enough with its long pinnate fronds. The azure heads of the sheep's-bit scabious, an old acquaintance, were peeping everywhere.

Pursuing the high road a few rods farther, we arrived at Holne Bridge, a solid granite structure that spans the Dart, well clad with ancient ivy and ferns. From the roof of its main arch depend stalactites, nine inches or more in length, formed by the free lime of its cement, each one bearing evidence, in its terminal drop of clear lime water, surrounded by a thin and brittle coat, of present increase.

Here we loitered for hours, lounging under the cool shadow of the bridge, admiring the *Jungermanniæ* and mosses that so luxuriantly cushioned the beetling hollows of the rock;* or gazing alternately up and down the river, from above the bridge and from below—up, where the stream comes brawling and sparkling down, curving round from the heights of Buckland woods, a mass of white foam, broken by dark rocky boulders; below, dark and mirror-like between tall beech woods on either bank; or peering, with that strange fascination which impels one with an ever increasing power to plunge in, on the deep hollows, so black and yet so smooth—so treacherously and invitingly smooth—"like sin," as my little son said.

I did not estimate the height of the bridge, but from recollection I should think the arch about twenty feet above the water as I saw it. Yet I was assured that occasionally the river is so swollen that the flood completely fills the arch. It must be a grand sight to see such a body of water, far exceeding the limits of the rocky bed, and filling a wide expanse of the bordering valley. It would then be a large river, and worthy of the lovely scenery by which it is encompassed; and, pouring down with its characteristic impetuosity, an impetuosity justifying its name of "Dart,"—it must, I say, be a grand sight. The floods of this river are extraordinarily sudden. After heavy rains in its elevated sources, far up in Dartmoor, of which perhaps not a drop has fallen here, the swollen waters come bearing down, all without warning, in the form of a mighty wall, like the bore of the Ganges in the monsoon.

Like the Lea near London, the Dart has the reputation of being peculiarly fatal, not a year passing without one or more persons being engulphed by it. This belief is embodied in a provincial distich:—

> "River of Dart! River of Dart!
> Every year thou claimest a heart."

The swiftness of its course, and the great unevenness of its

* *Splachnum ampullaceum* was particularly large and fine here.

bottom, full of treacherous holes and pits, combine with these sudden floods to give it such a character. People speak of its shrill wailing rushing sound as "the river's *cry*;" and say that during the stillness of night they hear it a long way from its banks.

Some little distance above the bridge the shale forms a noble precipice, rising with a rough face almost perpendicularly from the water's edge. It is crowned with fine timber, which descends on either side to the river. A romantic story cleaves to this cliff. A too-confiding maiden, deeply wronged by her lover, leaped, Sappho-like, from the summit; and hence the sheer descent bears the name of the Lover's Leap.

We heard a good deal of Widdicombe—"Widdicombe in the cold country;" "Widdicombe in the Moor;" "Widdicombe in the Dartmoors;"—"you *must* see Widdicombe by all means." Our curiosity was excited, and we set out. We wished, too, to see Widdicombe Tower, that tall embattled structure noted for its architectural beauty, and not less for its having been the scene of a most fatal elemental war. A terrible thunderstorm burst into the church during afternoon service, Oct. 21, 1638, and besides crushing and defacing the material building, killed four persons, and more or less wounded sixty-two. One of these was slain with unusual circumstances of horror. "Another man," says the local record, "had his head cloven, his skull wrent into three pieces, and his brains thrown upon the ground whole; but the hair of his head, through the violence of the blow, stuck fast to a pillar near him, where it remained a woful spectacle a long time after." Tradition affirms that the sufferer was sacrilegiously playing at cards in his pew at the time, and that it was the Prince of Darkness himself who, riding on the thunderbolt, accomplished the vengeance.

Well, Widdicombe and its tower must be seen. So we set out in the hard grey morning, leaving Ashburton by another outlet, a street sufficiently sordid, where the little river Yeo purls alongside the causeway, and disappears from the eyes of passengers to wash the back doors of the old quaint houses, and where dingy women are ever going up and down steps with pitchers and kettles. We get beyond houses and bridge, and pass as usual between walls bristling with feathery ferns, evidently the invariable in the outskirts of this little town.

The ground now rises fast, leading us through a high banked road or lane (I scarcely know which), where the male fern is profuse and fine, and the brake is also large and succulent, and delicately green. Ferns appear to have their proper domains. Presently these disappear, and it is all the black spleenwort with enormous fronds, so elegant in their triangular outline, and dark glossy greenness; and by and by nothing

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but the hard fern springing out of the loose stone walls. Oaks stretch their arms above the road, and make an almost continuous canopy, through which the twinkling sunbeams struggle and play with soft pellucid yellow green light; anon these give place to sombre firs, dull, stiff and skeleton-like—the plantations of Welster.

A conspicuous object all the way up has been the works and tall scaffolding of a mine on a hill to the right. We are told its name is Druids' Mine, and we at once think of the Phœnician times; but no! it is a thing of yesterday—a London speculation of some five years' starting.

We toil up past the mine, and getting behind and above it have a fine view of the valley to the east, and of the country toward Newton. A tall hedge of dwarf beech bounds the road on one side, and furze thickets on the other. Here my entomological son got his first prize, for we saw specimens of the beautiful little green hair-streak, which presently became sufficiently abundant, and continued the characteristic butterfly up to the moor.

The driver pulls up, and pointing to the left says, "This is Welster Beacon." We look and see nothing to tempt us to get out. "No; but just over the brow you'll see Buckland Beacon, about a quarter of a mile further on; and that is one of the old Tors, where you'll see a good sight." We dismount, clamber over a gate, and are on a wide rounded hill, covered with button-like clumps of mingled heath and furze; a broad grassy path leads us to a rough stone wall, and there the Tor stands revealed in its majesty, with its conical crown of grey stone.

We are soon on the summit, gazing with eager eyes on the almost boundless expanse which stretches away on every side. It is a noble prospect. Unfortunately there is a haze in the air, which diminishes, though it does not destroy, the distinctness of the several features. The eye is first attracted by the winding sparkling Dart, which seems to be beneath our feet, as we trace it coming in from the distant moor, and then encircling in its twining embrace the lovely Holne Chace, which, with its rich timber-woods and its curving drive, looks from this height just like a villa garden with its gravel walk. Thence the charming river is seen, white with foam (I unconsciously listened for its babblings), meandering away to the south, till the tall woods conceal it. There too was Buckland Mansion, dwindled to a toy-house, and the grey church tower rising from the embosoming trees a little behind it. Beyond and around were the map-like fields of many hues chequered out with hedges, and far on the south-west horizon the blue Brent Tor.

In the foreground to the south there is Answell or A's'ell Rock, a very remarkable Tor, crowning an eminence considerably inferior in elevation to that on which we stand. Viewed from hence, it takes the form of a colossal lion couchant, with a second granite mass, that looks like an armadillo, or, if you please, the great fossil tortoise of the Siwalik, marching up behind him. The buildings and tall shaft-works of Druids' Mine, a little to the left, stand out bold and prominent. All the east is dim, and obscurely empty; but on the north rises Hay Tor, a fine purple cone of lofty stature, and the wide grey moor stretching away to the westward, a dreary, tabular, unvarying mass. The sides and slopes around our feet were spotted with a few semi-wild sheep, which we fondly concluded made the well-flavoured Dartmoor mutton, that the reader doubtless wots of; but the driver subsequently undeceived us as to this point. The true breed is found only on the moor proper, which we have not yet come to.

We descend perilously, for the granite is angular and rugged, and the short wiry turf particularly slippery. Besides this there is little vegetation, save the tiny bedstraw, profuse in white bloom, crowding the rocky crevices, and the rosy white stars of the English stone-crop, and a twine or two of ivy mantling the grey stone, and abundant lichens completely covering the old weather-worn surfaces. A pretty little yellow cinque-foil studs the short turf with its flowers, and on the rounded hill there is the furze. This is singularly close and dense, forming rounded knobs, as even and shapely as the well-shorn shrubs in a Dutch garden; the wind doubtless having performed the shearing operation here.

The mass of granite has a very noble and impressive aspect, as we gaze up upon it from the point where it breaks out of the turf. It takes somewhat of the form of an immense table, rising to a low cone in the middle, or something like a huge loaf that has sunk in the baking. The vast block of primeval stone, naked and hoary, is imposing in its severe simplicity, as it stands out broad against the sky, with no object around on the bare hill to distract the attention; and it derives a great extrinsic interest from its associations with early, perhaps even prehistoric, times. This is Buckland *Beacon;* and I picture to myself the pile of combustibles which in seasons of danger or other expectation was wont to stand on that massive table, and the wild form of the appointed watcher, possibly the bearded Druid himself, rushing up the hill with his flaming brand, and hurriedly lighting the pile. Then I see the fire lick up the heap of crisp and sun-dried leaves, catch the faggots of furze, and, overpowering the cloud of blinding smoke, burst forth into a grand pyramid of flame, whose leaping and curling tongues

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rustle the scorched air, and roar like a tempest, while the red glare falls on the lone waste around. Then in an instant the attendant, gazing wistfully into the darkness, sees the answering fire blaze out on the summit of Rippon Tor, and, presently it may be, another spark, just discernible, tells that a more distant beacon has caught the signal, and sent it on; and he knows that before he can descend the slope and reach his lone hut, the whole of the wide moor will be studded with points of flame, and all the dwellers in the wilderness will have received the communicated intelligence.

Perhaps the ordinary occasion on which these signal fires were lighted may have been the approach of the Tyrian galley coming to trade for tin. The estuary of the Tamar has been shown on almost irresistible evidence to be the ancient Iklis, the port whence the Phœnician tin trade was carried on. Thither the accumulations of "silver, iron, tin, and lead," which the mines of this rich metalliferous region were yielding to the labour of a not unskilled and uneducated population, were brought for sale and barter; and thence the purple and fine linen of Tyre, the elegant manufactures of the Sidonians, the gold and precious stones and spices of India, and perhaps even the silks of distant China, were distributed through Britain.*

The arrival of the periodical galley from Tyre would then be an event which would put in motion the entire mining country; and we may well imagine that a series of signals would be concerted, by which it should instantly be known. These lofty Tors were admirably calculated for such a telegraphic system. Yonder blue mass in the south—Brent Beacon—overlooks Plymouth Sound and its approaches, and the appearance of a sail on the distant seaward horizon would not fail to be noted in fine weather. "What would be done," do you ask, "if the galley made the coast in misty or hazy weather?" I suppose in such case a signal fire would be lighted on the heights around the Sound, as soon as it became clear.

The flame from Brent would be responded to by Buckland in this direction, and by Sheep Tor in the west; from the former the news would flash to Rippon or Hay Tor, and be known then over the whole eastern region; from the latter it would be caught by Tor Royal, and thence by Crockern Tor, that seat of the Druidical legislature, and by Great Mis Tor, whence it would dart to Fur Tor and Yeo Tor, and to Watern Tor, that overlooks that wild lonely lake whence the Devonian rivers take their rise, and to Cawsand Beacon, from whose towering top the flame would be visible at once from both the

* See Heeren's Hist. Res.; *passim.*

northern and the southern sea. The distinguishing title of "Beacon," which immeasurable tradition has connected with some of these eminences, in no wise differing from their sister Tors, indicates the use which they subserved.

Reluctantly we leave these imaginings and turn our backs upon the ancient pile, Willie first rooting out a crown of the hay-scented fern from the foot of the "clatter," as a mass of granite so situated is provincially termed, and bagging a tiny lamellicorn beetle, and one or two more of the hairstreaks, that were fluttering over the furze-clumps.

We ride on, to make up for time lost in dreaming dreams of three thousand years ago, between the old roadside walls, made of granite blocks, rounded now by the effects of frost, and wind, and rain, and completely encased in lichen coats of many hues. Here the broad buckler-fern becomes the predominant form, remarkable for the very peculiar aspect produced by the recurvation of the edges of its pinnules, as if the plant had been just blighted by some baneful application, while yet retaining its succulency and greenness. The hard-fern and the male-fern, however, still occur also; the former unusually fine and well-grown. Great agarics too, and agaric-shaped *boleti*, are conspicuously numerous all along the road in this region. We pass through a gate, and are told that we are on the Moor.

A wide, desolate, heathy waste it is, undivided by fences (at least where we are travelling), but intersected by the high road. It did not oppress me with its loneliness; for the sun was bright, and horses were grazing, and sheep bleating, and butterflies were fluttering, and large handsome dragon-flies were hawking to and fro on rustling wings over the rain-pools in the sand-pits.

So we jog along, opening and closing in turn one and another of these wild fantastic heights, whose outlines ever change as we pass, and admiring the playing lights and shadows over the dark purple surface of the moor, as the clouds borne by the breeze expose or conceal the sun. The brooks enliven the waste, pouring along in haste, and sparkling among the granite boulders of their beds. Several of these cross the high road, the feeders of the Webbern, itself a tributary of the Dart, affording clear cold draughts to our thirsty throats, but with a somewhat ominously brown tinge and moory taste.

At length we emerge on a wide and most lovely valley; farms and hamlets scattered about its slopes, each, surrounded by its half-concealing groves of dark trees, look like oases in the wilderness. Some distance up the vale, which bends away from sight between the hills, we see the lofty church tower of Widdicombe, a fine gray square pile, of what is called the Per-

pendicular style, with four pinnacles at the corners. It rears its head far above the village, which seems to nestle among the embosoming groves as if desirous to be unseen. It is the frontier of civilization; far beyond all is the wild and naked moor. Imagination rests awhile on those sweet slopes, mapped out into fields, and spotted with clumps of noble trees, most of them ancient sycamores; and then, gathering its garments tightly round, strides onward into the unknown waste that lies among those sweeping moory mountains.

We did not go down into the village, but having satiated our eyes and our fancies, more ignoble, but not less clamorous propensities put in their claims for attention. Sitting down beside one of the gurgling moor-streams, we spread our frugal provisions on the short turf, pic-nic fashion, and ate and drank with gusto. Then strolling down the rivulet a few paces, I found it dilated into a shaking bog, where footing from clump to clump of furze, and from tussock to tussock of grass, was both scarce and precarious. I had been told that a singular and highly interesting plant, the sun-dew, that has the power of capturing unfortunate flies which rest on its leaves, grows in these elevated bogs, together with some other scarce plants, as the asphodel, and the beautiful little bog pimpernel. I found, however, neither of these, but the bright-eyed, laughing forget-me not, whose appeal I chose to read as made on behalf of the charming Vale of Widdicombe in the Dartmoors; and this I do not think I *shall* very readily forget.

Just as we were setting out to return, we had a curious evidence of the lonely and habitually undisturbed character of the place in the conduct of a little bird. A skylark descending came down close to us, singing as it came; and lowering itself on wide-spread wings, slowly reached the turf within a yard or two of our feet, without the slightest manifestation of fear, or even consciousness of our presence. A more unwelcome creature, but by reputation highly characteristic of the moor, crossed our path in the form of a viper, which the driver speedily demolished with his whip. It was the red variety, very distinctly and elegantly marked. The common people here call these reptiles by the strange name of *cripples*—a most unaccountable appellation surely. Musing on its etymology, it occurred to me that possibly it may look back to the Roman dominion, and may be the Latin *coluber*, the letters *l* and *r* being anagrammatically interchanged.

Another excursion of much interest was one that led us by Sharpitor and Dartmeet, to Wistman's Wood.

After striking the Dart at Holne Bridge, we cross and proceed through Holne Chace, a picturesque wood, from which the timber has been weeded out. Between the road and the river

our attention was directed to the enormous stumps of trees that had been felled even with the ground. The driver—the usual authority for tourists—informed us that the proprietor a few years ago cut timber from this property to the value of £60,000, which he bestowed as a fortune upon his daughter. The magnificent mass we are looking at was the base of the "queen" tree; the "king," of still superior vastness, is on the opposite side of the river.

Another quaint little bridge crosses the winding Dart at a most charmingly wild spot, having passed which, we rapidly ascend, and approach Leigh Tor (pronounced Léftor), a remarkable ridge of granite, crowning an eminence, which runs for some distance from east to west. We alight to examine it. It consists of enormous blocks so thrown up as to present a sharp angular keel to the sky, of course irregular and broken, and much more vast than it looks from the road. There was something very noble in its rude magnificence, as we stood against it. The common polypody in profuse abundance was creeping about the sides and points, making thick carpet-like draperies of its many bright green pinnate leaves, while in the dark crevices and obscure holes, overhung by the leaning blocks of stone, the broad buckler-fern was fine, and wood-sorrel displayed its three-fold foliage.

The woods of the Chace, through which we are still winding, are very beautiful; they are chiefly oak, but there is a great deal of birch, sufficient to give quite a preponderating character, and the light mobile foliage of this tree, "the lady of the woods," contrasts well with the massiveness of its lordly companion. Ferns too are very abundant and luxuriant, especially the *blechnum*, which I never before saw so fine.

The travelling becomes increasingly steep; the prospect behind and on either side wider and grander; the country through which we are passing is more than usually picturesque —old fashioned farm-houses, a primitive inn, an antediluvian smithy, and people as unsophisticated as the region; little brilliant streams crossing the road at every turn; fence-walls of huge, unformed granite blocks;—these at length bring us slowly and toilingly upon the moor.

And now we are in the midst of the Tors. Here they are, on every side, Pelion upon Ossa, Ossa upon Olympus! Away on the left, or, as a seaman would say, broad upon the larboard bow, rises from deep valleys a vast mass, of great regularity in outline, terminating in a sharp cone of gray rock. Other hills are beyond and on each side, but there is a grandeur in this which arrests the attention. Presently the road turns, and we see that we shall have to skirt the very flank of the mountain. A passing peasant, of whom we inquire its name, tells that it is

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Sharp Tor, or, as he pronounces it, Sharpitor. As we pass, we perceive that its broad side bears antique remains, and jump out to explore. Yes; here are indubitable relics of man's handiwork. We are standing in the midst of a circle, about fifteen yards in diameter, as I measured by pacing, composed of great primary rounded blocks of granite. Besides these, however, there are the débris of the elevation, in heaps of smaller stones which lie at the base of the primaries, making the walls in places two yards or more in thickness. The primary stones are placed in contact, not separated by interspaces, and therefore this was a dwelling-house, not a temple or sacred inclosure. There is an avenue of parallel stones leading from the circle away towards the south-east, that is, to the nearest point of the Dart.

The great size of this circle, as compared with the ordinary hut-circles, which rarely exceed nine yards in diameter, is remarkable. It is not sufficiently wide to inclose a village, nor to serve as a "pound" for cattle. It would rather seem to indicate the residence of a chief, but I did not notice any second circle within the inclosure.*

The bright, laughing sunshine and the dancing butterflies were not favourable to those solemn reveries which the same scene under the silent moonlight, or in a twilight storm, would have conjured up. Yet it was not without a feeling of awe that I reflected on the hoary ages that had passed away since a man of like passions with me brought home his loved bride to that now lonely dwelling, and "his young barbarians all at play" made the air ring with merriment as they ran around those gray wall-stones, or chased the identical forefathers of those very butterflies over the moor. "How long was that ago?" How long? Who knows? Perhaps when Jephthah was offering up his burnt-offering; perhaps when Caleb was carrying the cluster of Eshcol.

Yar Tor rises just opposite to Sharp Tor, on the right hand of our road. This eminence is crowned by a strong wall, forming a square inclosure, formed partly by nature and partly by art. On the north-east slope we saw "the remains of some hut-circles, and the ruins of a kist-vaen," which are there; but time pressed, tokens of a storm lurked in the horizon, and I specially deprecated our being disappointed of seeing Wistman's Wood. We were therefore constrained to hasten past these interesting antiquities without examination.

* I took for granted that I should find full details of this remarkable circle in Rowe's *Perambulations*, which I referred to as soon as I arrived at home, but to my surprise he does not notice any remains on this side of the hill. Had I anticipated this silence, I should have made a more minute examination; the notes I have recorded above were, however, jotted down in my note-book upon the spot, and may therefore be depended on.

From the skirts of Yar Tor, looking south, the view is suddenly opened by our having left Sharp Tor in the rear; and the rounded hills which form the valley of the Dart take majestic forms, and have an aspect of sullen grandeur, but the river itself is not here visible.

Soon, however, we see it before us; and descending abruptly we come to a small bridge, by which we cross the East Dart, just before its junction with the West Dart; the spot itself and the bridge bearing the name of Dartmeet. The view up the east branch is extremely fine: the stream being very swift, and full of rocks, the wild riotous turbulence, the dashing, flashing water half lost in foam, and the high-toned metallic cry, take strong hold of the imagination. Looking up the west branch, and down the united stream, the aspect has the same character.

Beside the road which rises from the bridge, the elegantly cut lady-fern suddenly becomes so abundant as to be characteristic, throwing out its arching fronds from the walls, mingled, however, with the everywhere profuse hard-fern and brake.

Far up on the naked moor a little black object appears, to which our attention is drawn. We might have imagined it a traveller's portmanteau dropped from a carriage, or a bit of india-rubber left by a sketcher, so minute it looks on the desolate mountain-side, with no other object near with which to compare it. We are told it is a school; a school endowed by two benevolent ladies. A school forsooth! we should almost as soon have expected a coffee-house or a jeweller's shop. Where do the children come from? we asked. At last we reach it, the road leading by the door. It is built of corrugated iron, like a temporary railway station, and, however we might have doubted the call for such a building, there are the urchins within. Through the open door we see them sitting at the desks, gazing furtively at us, doubtless envying us freedom, and a ride. The school rejoices in the euphonious appellation of Brimps.

Not far from this our civil and intelligent driver took fire at the occurrence of a wall, which he had not seen before, not having been so far from home for a twelvemonth or more. It is a noble wall, well-built of massive blocks of granite split out of these endless Tors, and put together without the least bit of cement; the solidity and weight of the pieces affording the requisite stability. Wide interstices between the blocks are left purposely, that the force of the wind may not act unbroken. What a shrill wail these varying orifices must utter in a high autumnal gale! The immense size of the blocks, contrasting with those of the ancient walls around, shows the resources of modern art; for this wall is built by Government. It was this

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that stirred the wrath of our friend, who protested eloquently against the encroaching policy of the Duchy of Cornwall, robbing, as he averred, the poor moormen of their scanty pasture. At first we could not see the object of the inclosure, but presently a healthy plantation of young firs within the grim fence explained it.

All before us spreads the wide moor, ever wilder and wilder. Solitary farms smile at distant intervals in the bottoms. One of these, Sherbiton, prettily surrounded with trees, by a brook, specially attracted me. Abundant springs of water occur everywhere; the moor is evidently a Jamaica, a "land of springs." Far away in the west we see Princeton and the War Prison, which at one time held ten thousand prisoners. Grim and gaunt it stands on the naked mountain side, encircled by its gray granite walls. On the right of this uninviting object, but much more distant, a magnificent Tor rises against the sky, striking the eye by its noble outline and manifest elevation, pre-eminent above its fellows, and exciting curiosity to know its name. At length a peasant informs us that it is Great Mis Tor.

This is one of the loftiest peaks on the moor, and appears to have been a chief seat of the Druidical astrolatry; at least, if that etymology of its name be sound, which derives it from Misor, the British moon-goddess, answering to the Ashtoreth of the Sidonians. The out-croppings of the granite on the summit of the Tor are described as taking magnificently massive forms, and, on the top of the loftiest, at an elevation of 1760 feet above the sea-level, there is one of those singular circular pans which have provoked so much discussion as to their origin. From their situation, and the regularity of their form, it has by some antiquaries been maintained that they were connected with sacerdotal service, used either for the washing of the sacrifices, or the ceremonial lustrations of the priests, and that they were excavated by human skill and labour. Others believe that, beautifully regular as is their shape, they are merely the result of natural decomposition. If so, however, they are not the less likely to have been pressed into the service of the dominant idolatry. The one on Mis Tor, commonly known as Mis Tor Pan, is remarkably smooth, and perfect in its outline, about eight inches in depth, and a yard in diameter.

However, this was far beyond our present limits. We jog on by Hockaby Tor, a crowned eminence on our right of no great elevation, but interesting, because on its slope there are several hut-circles distinctly visible from the road, distant from it, indeed, only a few rods. We ford Oxlake Brook, a little feeder of the West Dart, which we see winding among the hills

at our left, running nearly parallel with the road, and forming brilliant little pools here and there under the midday sun. The slopes from Sherbiton are covered with boulders, which *may be* ruins, but which appear from their wild confusion and ruggedness to lie where they were protruded in some primeval convulsion of nature. Their number imparts an unusual aspect of savage desolation to the scene. Here on a granite block was sitting a yellow-ammer preening its bright plumage in the sun, and all unconscious of sadness. The local name for this familiar little bird is "gold-gladdie;" a pretty appellation, well suited to the appearance of a gay-coloured bird in a lonely and desolate region.

Our road now is bounded on one side by the wall of Dinnabridge Pound. Within the enclosure near the gate there is a lichened chair of granite, evidently of great antiquity, which tradition asserts to have been brought hither from Crockern Tor. The Pound itself is comparatively modern; it is a large inclosure, surrounded by one of the dry stone walls so universal here. It owes its origin to the customs of the moor. The entire forest is farmed out under the Duchy of Cornwall to certain persons termed moormen, who receive cattle for pasture, affixing to each animal "the moorman's mark." On one day in the season, of which he gives no notice, the moorman drives all the cattle on his quarter to a given spot, and impounds every one that has not his mark.

The sheep and cattle, though allowed to wander apparently without restraint, are said always to keep company with those of their own flock or herd. We could see this to be true with respect to the sheep: though we passed a great number in our course over the moor, we never saw those marked with one colour or set of letters mingling with those otherwise marked; they associated with their own exclusively. These are true "Dartmoor muttons," a little breed, which you would think to be lambs. The sun was powerful, and the poor things in this shadowless region were fain to creep up under the north side of the stones, and even at the sides of the shallow pits whence turf had been dug, as an apology for shade, though even when they lay down more than half of their bodies were in the full blaze.

Just beyond Dinnabridge Pound we see a fine Tor, which bears the name of Belevor, one of the numerous eminences in which the name of Bel or Baal is traced—a remnant of the Oriental idolatry which spread its baleful wings over this region in primitive ages. The country hereabout is full of aboriginal monuments, and the Tors rise thickly on the right and in front of us; the mountains bristle with rocky peaks and points, like monumental stones in a churchyard—grim memorials of the

long, long past. Conspicuous among them is Longaford Tor, with its sharp conical crown, and in the foreground Crockern Tor, once a place of renown.

On this bleak and desolate mountain, in the midst of these hoary stones, with only the sky for a canopy, be it clear or cloudy, bright sun or driving rain, soft zephyr or howling storm, met the ancient Stannary Parliament. Each of the four Stannary towns, Chagford, Ashburton, Plympton, and Tavistock, sent twenty-four burgesses to this assembly, when summoned by the Lord Warden of the Stannaries. They enacted laws, which, when ratified by the Lord Warden, were in full force in all matters between the tinners, "lyfe and lym excepted." Probability and tradition, however, assign a far higher sanctity to this spot, as the seat of Druid legislature. The Stannary Court was but a form, comparatively modern, of an assembly which had been wont to meet there from earliest times. Polwhele says that in his time there were the president's chair, seats for the jurors, a high corner-stone for the crier of the court, and a table—all rudely hewn out of the granite of the Tor, together with a cavern, which may have served as a dungeon for the condemned. A moorland patriarch who had known the spot for threescore years, told Mr. Rowe, in 1835, that he perfectly remembered the stone chair, which was ascended by four or five steps, and that overhead it was protected by a large thin slab of stone. There seems to be little doubt that this chair now stands in Dinnabridge Pound.

A strange feeling pervades the mind as one stands thus amid the memorials of a hoary and dim antiquity, and calls up the gathering assembly, with its stoled priest and its sucking lamb, and perhaps other sacrifices, from which imagination hides her face, dripping blood on these huge stones—perhaps at the very time that Samuel was judging Israel in the circle of Gilgal, and obtesting at the stone of Eben-ezer. The nakedness and utter desolation of the region still and solemnize the mind, notwithstanding the cheerful sun and the swift chequering clouds. In the shadows of evening it must be an awful place, when fancy would people it with the shadowy ghosts of four thousand years, and every stone would take form and life.

Again we descend to the river at a place called Two Bridges. There is, indeed, but *one* bridge that I could see or hear of, and the only way I can account for the name is by supposing that there existed, coevally with this modern structure, one of those very ancient ones, usually described as "Cyclopean," made by upright monoliths for piers, and enormous slabs of granite made to rest on these horizontally, the stability of the whole depending on the immense weight of the blocks. Several of these interesting bridges yet remain to attest the

solidity of their construction, particularly one over the East Dart, near Post Bridge.

Close to the river, at Two Bridges, a country inn of more than usual pretensions, surrounded by its offices, gives animation to the scene. The sign, once doubtless a fine example of high art, representing a robed and bearded personage, life size, now, from the painting having never been varnished, and the colours having fled, presents an appearance ludicrously ghastly. An antique ostler, curiously in keeping with the associations of the place, appearing, we inquired our way to the wood, the object of our search, while the driver dived into the recesses of the bar, to get "summat." The man of horses, with a ready civility, and a free use of "yir 'annor," which suggested a Milesian education, pointed up the valley of the Dart to the slope full in sight, at what appeared to be only a few hundred yards distant, where a very circumscribed thicket of scrubby furze (so it looked) was growing. "An' that," said he, "is Wistman's Wood; an' it's a mile and a half's walkin'."

My little son and I tramped away up the valley, the scrub still in sight every step of the way, which ever grew wilder and wilder. Through a dreary farm-yard we post, and the world is behind us. Our course is parallel to the Dart, which purls and rustles below, under the shadow, for some half mile or so from the bridge, of magnificent dark beeches. The utter absence of recognizable objects makes distances strangely deceptive. Still wilder and wilder grows the moor; here and there we suddenly find our feet press a shaking bog. No sign of animal life, but a pretty little butterfly,* which is numerous. Yes; in that little pool in the rocky stream, a trout leaps into the air; another, and another; though the dimensions of the pool are such as you might stride across, and its depth seemingly fathomable with your hand.

The furze begins to take form, and to look like dwarf trees, and far above frowns the blue peak of Row Tor, around which dark clouds are gathering. Now the granite blocks become thicker and more numerous, till we find ourselves crossing a wilderness of boulders, where we can proceed only by scrambling from one to another, there being literally no way between, the narrow interstices being choked with brake and moss, and the stone-crop. I never before saw a place which gave me such an idea of utter desolation. At length we reach a single solitary oak, the outpost of the wood, and after a little more difficult and dangerous scrambling over the blocks, we enter the weird forest itself.

I despair of conveying an idea of the strange scene by

* *Hipparchia pamphilus;* a variety much paler than the ordinary condition.

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words. The granite boulders continue as close as before, with the stunted and moss-gnarled trees springing out of the interstices. It is said that these narrow passages go down, down, to an unknown depth, and some have thought that we see only the summits of the trees, the trunks, of ordinary height, being rooted in the earth far below. I did not think of probing the treacherous crevices, which are reputed to swarm with adders; but there is that in the aspect of the trees which at once confutes this hypothesis; not to speak of the absurdity of supposing that the granite boulders have gradually accumulated since the existence of the trees.

That these oaks and rowans are enormously old I do not doubt. Those which I saw might have trunks a foot in diameter on the average, and their height is from twelve to fifteen feet. The branches are wonderfully twisted and knotted; the heads are scanty, flattened, and wide-spread; and both trunks and boughs are so thickly encrusted with dense moss, that ferns grow profusely upon them.* The foliage is not unhealthy; and I observed numbers of those globular galls, like a boy's marbles, which have lately attracted notice in South Devon. I saw no young trees, no suckers, no acorns. Individual immortality seemed to be conferred on these remnants of bygone times, but nothing that indicated transmission of life to another generation.

I should much like to see a section of one of these old trunks; to count the concentric circles, and thus obtain a clue to their actual age. At the Norman Conquest the wood is said to have presented the same appearance as it now does; and I should think it by no means an unreasonable conjecture that these identical trees have witnessed Druidical rites. The explanation of the name, "Wistman's Wood," as *wiseman's* wood, has been ridiculed; but, considering the ancient form of "*wist*," (from the Saxon ꝑíꝛꞇaŋ,) *to know*, it is highly suggestive: *q. d.*, the Wood, or Sacred Grove, where the *Knowing-man* performed his incantations.

By this time the heavens were gathering blackness, and from several points of the horizon those dark, ragged clouds were rising and hanging in tattered shreds, that tell of heavy rain. Mutterings of thunder, too, were audible; and notwithstanding that a thunder-storm in such a place as Wistman's Wood would have greatly augmented its melodramatic interest, yet neither on my own nor my sick child's account did I exactly wish to brave its results. We, therefore, hastened back to Two Bridges, casting many a wistful glance on the strange scene we had left, the like of which we might probably never

* *Polypodium vulgare*, and *Lastræa dilatata* and *recurva* profusely.

see again. It took a peculiar aspect under the glowering sky; and the distant peak of Row Tor above, lighted up by a momentary gleam of sunshine, came out wonderfully fine against the black storm-cloud.

Some points of interest occurred on the homeward route. Several hut-circles were seen close by the road-side at Haxary, where the West Dart gleamed beautifully in a romantic dell. Then we reached Compstone Tor, crowned with a fine assemblage of granite rocks of that peculiar form known as the Cheesewring; enormous slab-like masses of varying diameters, piled one on another horizontally: I say "piled," for such is the appearance; though doubtless the phenomenon is the result of elemental decomposition on the horizontally stratified granite. This arrangement has a very magnificent effect.

Benjay Tor, a lofty hill, which presents a precipitous face of broken stone to the bed of the turbulent Dart, was a striking object, the river forming two deep and dark pools beneath, which are called Hell Pool and Bell Pool. But, I think, as interesting as anything that I had seen, not excepting even the architectural remains and the old wood, were the traces of the ancient Tin-works. From Compstone onward to Holne, an elevated, heathy region, there occurred, at brief intervals, large tracts of ground which had been excavated to a shallow extent, and which have a very peculiar and easily recognizable appearance. They are of course covered with common vegetation, but the removal of the surface earth producing a depression of the level has an effect so unique, that the beholder, after he has had one or two of these "golfs," as they are termed, pointed out to him, readily detects one as he approaches it, and at once discriminates between these and any other irregularities in the country. These "golfs" are the spots where, in remote ages, the people searched for tin; the metal was found very near the surface, and was separated from the soil by the action of running water. A running stream (and this region abounds with such) was chosen, and so enclosed and directed as that its force should fall upon the metalliferous soil, when the lighter earth was washed away, and the heavier ore remained. This process was called *streaming;* and it is believed that the ancient tinners were acquainted with no other mode of obtaining the metal.

Near Ringershots, the driver pointed out to us an ancient tin-stream, and it was with curious interest that I examined it. It is a romantic little gully, or glen, close by the road-side, all overhung and concealed by mountain-ashes, where a tiny thread of water now trickles with a metallic tinkle down the black, boggy soil. It has probably been unused for ages, but tradition has preserved the record of its former use, though

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the water which once made it available has long been drawn into other channels.

Thoughts of the old Phœnician rovers came up before my mind as the shadows of evening gradually shut out the scenery; and in imagination I followed the white metal—scarcely less precious than silver—across the stormy Bay of Biscay, through the Pillars of Hercules, and up the Mediterranean, till I saw it spread out in the market of Tyre; and, amidst the concourse of traffickers, heard the voices of the eager merchant-princes, crying, as they strode in front of their stalls, "Bedil from Tarshish! Bedil! Pure Bedil! Bright Bedil! Buy, buy, buy!" And then there came a twinkling of blue, and purple, and fine linen; and a chaffering and charming of many voices; and a Babel-hum of confused sounds. But the familiar voice of the driver said, "Here we are at Holne Bridge;" and the vision vanished. Yet I was glad that such was the last impression I had of Dartmoor.

SPECTRUM ANALYSIS APPLIED TO THE STARS;

OR,

THE STARS, WHAT ARE THEY?

BY WILLIAM HUGGINS, F.R.A.S.

"Ye are a beauty and a mystery," sang the poet as he saw the stars mirrored in the crystal face of Geneva's lake. A beauty theirs, which time affects not, and which glows with undiminished lustre upon successive generations of men. But the coils of the mystery are loosening. One coil was unwound, when more delicate methods of observation showed that twin stars, in their close companionship, move about each other in accordance with the same laws of gravity by which our solar system is knit together and upheld. Another coil is now loosening, as by the continual watching of numerous observers, are being traced out the periodic curves of increase and diminution in brilliancy of those stars whose light is variable. Yet they remained a mystery still as to their substance. What are the stars? Matter, certainly, and matter analogous to that of which the sun and planets are built up, since it exhibits similar laws of attraction. But is this matter composed of terrestrial elements? Could our chemical notation be adopted by physicists in Capella, and Arcturus, and Sirius? This seemed a tightly-bound coil of mystery which human fingers could

scarcely hope to unwind. As long as the methods of chemical analysis required the substance to be within the grasp of the experimentalist, the attempt was hopeless. We could never expect to weigh fragments of Sirius, or measure in the laboratory the chemical influences of the Pleiades. Recently, Kirchhoff and Bunsen, skilfully combining the researches of numerous previous observers, have placed in our hands a method of delicately analysing many substances *at a distance*. Fortunately, the stars belong to the class of bodies to which *analysis at a distance* can be successfully applied. Light is the go-between, the bearer of a message which can be read as surely at 1000 millions of millions of miles as at ten inches. Light contains in hieroglyphic characters the names of the substances which exist in the source of light, and we are indebted chiefly to Kirchhoff for the key by which this writing can be deciphered and read.

Newton admitted a sunbeam through a small hole into a dark room, and caused it to be bent out of its course by placing in its path a prism of glass. He was richly rewarded by the separation from each other of the different coloured lights which, by their united influence, affect us as white light. Each of these being bent from its course according to the velocity of its vibrations, the sunbeam is spread out, the rays that have travelled together to us from the sun diverge from each other, from the red, which is least diverted, to dark purple, which is the most bent aside. Conceive of a fan, the sticks of which are coloured red, orange, yellow, green, blue, indigo, purple. Closed, it represents a sunbeam. Opened, the same sunbeam spread out by refraction through a prism. If in place of a round hole the light be admitted through a very narrow slit, so as to diminish the glare by the removal of the overlapping light, and certain other precautions be taken, it will be seen that the coloured rays of the solar fan are closely written over with dark lines. The whole of the spread-out sunbeam is full of dark lines, differing in thickness, and in shade of blackness, and arranged in definite groups. Wollaston first saw them. Fraunhofer, in 1815, published a map of the solar spectrum with six hundred of these lines laid down. To the principal ones he gave the names of the letters of the alphabet, though he dreamt not of what those letters would spell if rightly combined and interpreted. (See Fig. 1.)

Since that time, many observers have examined other lights than that of the sun, and it has been found when the light from metallic flames is similarly spread out by refraction through prisms, that the spectra resemble broken fans, certain of the coloured sticks being absent in some, certain others in others. Thus the light of sodium has only the yellow stick, and that is

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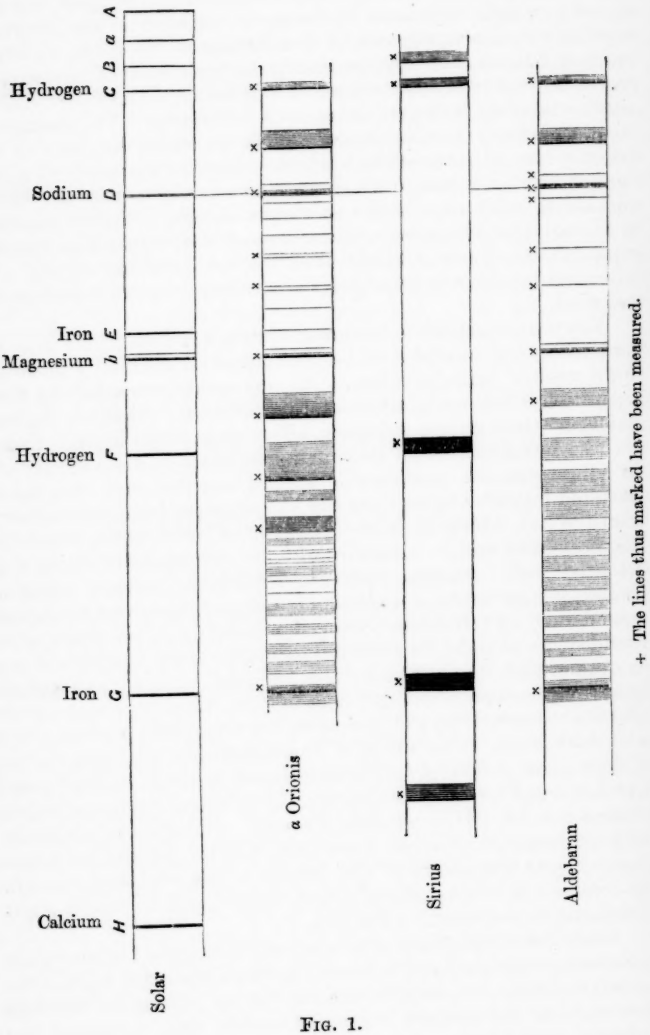
A
a
B
Hydrogen C
Sodium D
Iron E
Magnesium b
Hydrogen F
Iron G
Calcium H
Solar
α Orionis
Sirius
Aldebaran
+ The lines thus marked have been measured.

FIG. 1.

split in two. Each metallic flame has its own characteristic spectrum. The light is not a continuous shading into and mixing with each other of the prismatic colours from the red to the purple, as is the sun's light, but consists of sharply limited bars of light with dark gaps between. Each metal is thus individualized by the grouping in position of these coloured bands, by their relative intensity, and by their place in the spectrum. The appearance of each metallic flame, when thus examined, is as peculiarly distinctive as each man's countenance is unlike his fellow's, and fixes his identity. As increased light brings out upon a friend's face more minute individual traits, without changing those which are broadly marked and seen at first sight, so, in the case of most metals, increased heat adds to the number of the bright lines, but does not alter the grouping, or change the position of any of the lines of light emitted at a lower temperature. Thus the new metal thallium, the whole of whose light at a low temperature is concentrated into one intense green line, emits feebler lights of different refrangibilities as the heat increases, and when the electric spark is taken between points of thallium, eight other lines may be counted, in addition to the characteristic band of bright green.

So delicate a mode of analysis is thus afforded us, that a quantity of a solution of common salt which does not contain more than $\frac{1}{2,500,000}$ of a grain of sodium, will exhibit the well-known yellow band of sodium. More valuable than its delicacy, is the facility with which this mode of analysis distinguishes bodies in minute quantities which comport themselves similarly in respect to ordinary re-agents. In a ton of the water of the spring at Durkheim, besides chloride of potassium, are minute traces of two other chlorides, which would have remained undistinguished by ordinary analysis. Bunsen and Kirchhoff discovered them by their characteristic lines of light when placed in a flame. Two lines of celestial blue, and two dark red lines, revealed the presence of two hitherto unknown metals, cæsium and rubidium. The latter is a metal with which we have daily to do, since it exists in tobacco, in tea, in coffee, and in grapes. More recently, Mr. Crookes in this country, and on the Continent M. Lamy, by the same method, have independently added to our metals, thallium. This method of analysis not only detects traces of matter infinitesimally minute, but permits *unlimited distance to separate the experimentalist from the substance he would examine.* Hence it is not bounded by terrestrial limits, but can be brought to bear upon the sun, and the immensely more distant stars.

THE SUN.

It is to Kirchhoff that we are indebted for being able to take the bright lines of the metallic flames, and apply them as a key

to unlock the mystery of the dark lines of the solar spectrum. The dark lines are the shadows of the bright lines, or, more accurately, they are spaces of darkness where the bright lines would have been had they not been intercepted. Between us and the sun what is there to arrest the light? What arrangement of screens can exist which shall stop out these fine lines, and these lines only? The Heidelberg professor shows that the vapour of each metal is a perfectly opaque screen to light of the particular refrangibilities of its own bars of light, and yet perfectly transparent to light of every other refrangibility. Place common salt in the flame of a candle, in the spectroscope the double sodium line is sharp and distinct in the long continuous spectrum of the hydrocarbon flame. Now, cause sodium vapour to rise between the flame and the slit, the invisible vapour will intercept the sodium light as perfectly as a plate of iron, at the same time that it is clearer than glass to the light of the vapour of burning tallow. A fine double line of darkness will now be seen in the place occupied by the bright sodium bands.

Again, take a flame giving a continuous spectrum, such as that of a paraffine lamp, or the light emitted from an incandescent solid body, as lime in the oxyhydrogen flame, and, as before, cause sodium vapour to rise between the source of light and the slit of the apparatus; a finely double line of darkness will be seen exactly in the place which the sodium line would have occupied, had there been sodium present in the source of light. Such are the dark lines of the spread-out sunbeam; spaces of darkness, more or less intense, caused by the absorption of the light by metallic vapours, each vapour absorbing or intercepting its own group of lines. To decipher the dark lines of the solar spectrum, it is only necessary to compare the dark lines with the bright lines of burning elements, noting the coincidence of line with line, until, by the actual agreement in relative position of the whole group of lines, the name of the metal whose vapour is between us and the sun can be spelt out with certainty.

In Fig. 1 is a diagram of the solar spectrum, with the principal lines, from A in the dark red, to H in the purple, which is nearly the limit of the visible spectrum.

Fig. 2 shows a few of the lines contained in a small part of the spectrum, that bounded by E and *b*. These lines we have called hieroglyphic letters, and their power is due *to their position in the spectrum*, as if the letters of this page were similar in shape, and distinguishable alone by their distance from the margin of the paper. Hence the necessity for accurate measurement in position of the lines, and so minute must be this accuracy, that probably no certain results in deciphering

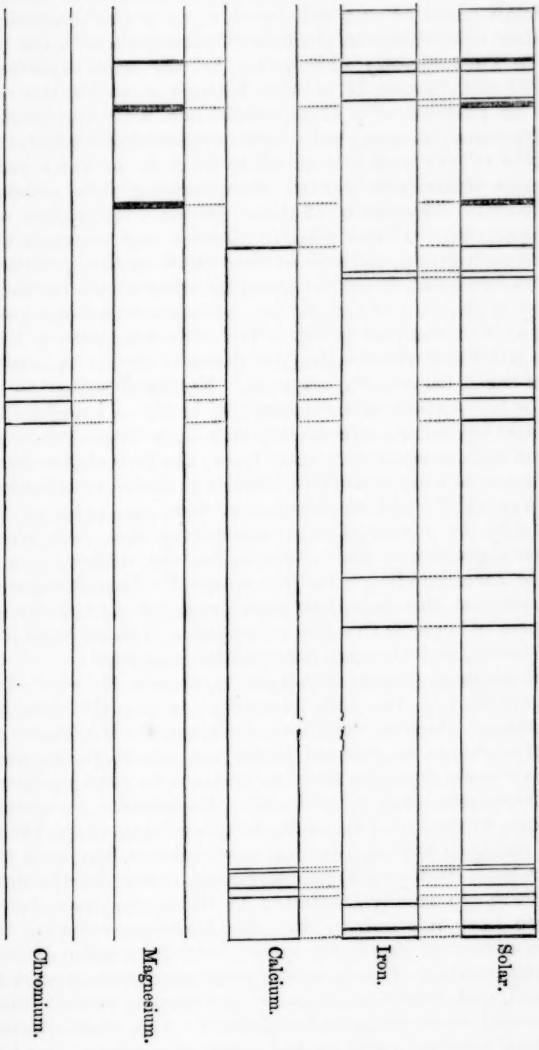

FIG. 2.

the solar lines would have been obtained, if apparatus had not been designed by which the solar spectrum and the spectra of the metals could be seen side by side, as in the diagram, and the actual coincidence in position of solar lines with the bright metallic lines directly observed. As the solar spectrum is crowded with thousands of lines between A and H, the coincidence in position of a single dark line with one bright line would possess, at most, but a light weight of probability. The attention of the reader is asked to Fig. 2, in which are seen the more remarkable groups characterizing four metals, and the absolute coincidence of these groups with groups in the solar spectrum. If the relative position and intensity of the lines of each group, as well as their place in the spectrum, be closely considered, it will be seen that what would be but probability in the case of a single line, advances to become proof in the case of a complex group. The strongest case is that to which Kirchhoff refers—the iron group of lines. A small part only of this is seen in the diagram. Kirchhoff writes :—

"In the portion of the spectrum, in plates 1 and 2 (from D to a little beyond F), about sixty iron lines appeared to me to coincide with as many dark solar lines; the probability that this coincidence is a mere work of chance is therefore considerably less than $(\frac{1}{2})^{60}$, and therefore less than $\frac{1}{1,000,000,000,000,000,000}$. This probability is rendered still smaller by the fact that the brighter a given iron line is seen to be, the darker, as a rule, does the corresponding solar line appear." It might as soon be supposed that this page has been produced by the fortuitous concourse of type, as that the coincidence of these large groups is accidental, and they are not causally connected.

But are these screens of metallic vapours *in the sun?* If not, where are they? The only alternative is to place them in our atmosphere, which is manifestly untenable. We know of no terrestrial causes to produce them, nor are there any laws by which we could conceive them to continue to exist as vapour in our atmosphere, even if produced. Experiment is against it. The lines, when viewed through a longer column of air, when the sun is rising or setting, are not more intense, but, as a whole, are less so. Under such circumstances, other lines come into view which are usually attributed to the atmosphere, but with these we have not now to do. Mr. Glaisher, referring to his balloon ascent of April 18, says: "At four miles above the earth the number of lines in the solar spectrum appears to be increased, and, therefore, none of the lines as viewed from the earth would seem to be atmospheric." The other alternative, that these vapours exist in the solar atmosphere, is what we should expect from the high temperature of the sun. Cosmically connected as are the sun and the planets, it was to be

expected that terrestrial elements would have a place in the sun. At present thirteen or fourteen have been read in the solar lines.

In Fig. 1, the reader will find the names of the metals against the principal solar lines, which these represent, according to the researches of Kirchhoff and Angström, with the exception of the line B, which Angström attributes to potassium. The writer's own observations show that the dark red band of potassium is closely approximate in position with A, but is not coincident with it, being in a small degree less refrangible. Kirchhoff leaves F undetermined. Angström and Plücker agree that F is coincident with the greenish blue band of rarefied hydrogen. Besides these the following metals are in the sun: nickel, cobalt, chromium, manganese, aluminum, and probably strontium and barium.

The most probable supposition from these facts is that, "the sun consists of a solid or liquid nucleus heated to a temperature of the brightest whiteness," and surrounded with an atmosphere of a somewhat lower temperature, in which are commingled vapours of all substances volatile at the solar temperature.

THE STARS.

If the constitution of the sun can be deciphered at ninety-five millions of miles, why not the stars at a million times that distance. The length of time the light is on its way will not affect the message it bears. It is written in language that never alters, recorded in characters that never become obsolete. The investigation, however, is hedged round with other and formidable difficulties. The light from the stars is comparatively faint, and yet if the lines are to be satisfactorily distinguished, this light must be spread out to a considerable extent. The slow, measured march of the heavenly host from east to west may be counteracted by clockwork attached to the telescope, but not so the continually moving currents, and ever changing want of homogeneity of our atmosphere. The last difficulty reduces to but a small number during the year the nights on which the finer lines can be seen and mapped.

The writer of this article, in association with Professor W. A. Miller, entered upon this very delicate inquiry in January, 1862. A few broad bars in the brighter stars were soon seen, but considerable time has been consumed in perfecting an apparatus, by which *the true stellar spectra*, which, like that of the sun, consist of *numerous fine lines*, could be well observed and accurately measured. The investigation is being carried on in the observatory of the writer, at Upper Tulse Hill, near London. The specially constructed spectrum apparatus is attached to the eye-end of his telescope. This is a refractor

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of ten feet focal length and eight inches aperture. The object-glass is a very fine one, and does credit to the skill of Alvan Clark, of America. The equatorial mounting is the work of Cook and Sons, of York. The special spectrum apparatus is so constructed as to concentrate the whole of the light gathered by the eight-inch object-glass into a short and fine line of light. This then passes through the dispersing portion of the apparatus, which is sufficiently powerful to show distinctly the fine nickel line within the double D line, when it is directed to the sun. The micrometrical arrangement by which the position of the lines is determined will measure the $\frac{1}{2000}$th part of the interval between A and H. Absolute measures would be of little value, unless they were accurately comparable with similar measures of the solar lines. This has been provided for in the apparatus, which is so constructed as to permit the light of any flame to be thrown into the instrument, and its spectrum viewed directly with that of the star. A sodium line thus seen has been selected as a fiducial point of measurement, and its position in the apparatus verified by observations of the sun, when it is found to coincide with D.

Last February a "note" was sent to the Royal Society, containing, as an earnest of the results of the observations of Professor W. A. Miller and the writer, the diagrams of the three stars which accompany this paper.

Previously to this, little advance had been made upon the observations of Fraunhofer, in the beginning of this century. He recognized the solar lines in the spectra of the Moon and Venus; and also measured some three or four lines in Procyon, Capella, Betalgeus, Castor, and Sirius. Donati's recent elaborate paper contains several additional stars, but in no case has he given the positions of more than three or four bars. The investigations of Fraunhofer and Donati were both undertaken to determine if the light from the stars is identical with, or differs from, solar light in its refrangibility. It is believed that the investigations of the writer and Professor W. A. Miller are the first that have been undertaken with a view of determining *the constitution* of the fixed stars. Quite recently three other observers have published results—Rutherford in *Silliman's Journal* for January, 1863; Secchi, in the *Nachrichten*; and the Astronomer-Royal in an oral communication to the April meeting of the Royal Astronomical Society. As the results which these observers have given are inferior in completeness to those arrived at by the writer, he will at once ask the reader's attention to the diagrams of Aldebaran, Sirius, and *a* Orionis, in Fig. 1.

A single glance will show that the fixed stars have been created upon the same general plan as our sun, and yet that to

this unity of plan is added variety of purpose in the different grouping of the elements composing each. In Aldebaran and *a* Orionis will be seen a line coinciding in position with D, and indicating the presence of sodium in these stars. In Capella, Arcturus, and other stars, a sodium line is also present. In Capella, the writer has seen this line to be finely double, as upon close inspection of the solar spectrum in Fig. 1, the line D will be seen to be—a proof that may be considered conclusive of the presence of the metal sodium. The C, hydrogen, line is also present, and this probability is rendered stronger, by a line in each star coinciding with the other hydrogen line F. Amongst some fifty stars observed, a very large number, if not all, have a line corresponding to F. This would show that hydrogen—the element upon this earth, next to oxygen, perhaps, the most widely present, and equally essential with oxygen to the structure of everything that has life—is also very widely diffused through the universe. Magnesium and iron would seem to be present in a large number of stars.

The writer and Professor W. A. Miller consider the direct observation of the coincidence of stellar with metallic lines so important, that they intend not to rely upon measures, but to compare the metals directly with the stars. This has already been done with some metals.

It must be remembered that a few only of the lines seen are laid down in the diagram. Most of the star spectra appear to be as full of lines as is the solar spectrum. Other lines have been seen in Sirius, in the orange and in the green.

If these distant suns have thus an analogous constitution with our sun, may we not suppose that the planets which, doubtless, they uphold and energize, are of like material structure? And if terrestrial elements, with their properties unchanged, be present, may we not further surmise, that life in forms not wholly dissimilar to those on this planet, and which these elements are so eminently adapted to subserve, may not be wanting. The spectrum of solar light reflected from the planets has also been observed. Numerous lines have been measured in the spectra of Venus, Jupiter, and the Moon. They have also been recognized in Saturn and Mars. No addition or change of lines has been seen to indicate that the light has undergone any change by reflection from them. It is probable that, with the exception of the Moon, we receive the light reflected from clouds or vapour in the atmosphere of the planets, and not from the true planetary surface. The light would not, under these circumstances, pass through so great a length of planetary atmosphere, and in the same proportion would it be less liable to have any modification impressed upon it.

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TEMPERATURE OF THE SUN AND STARS.

Besides the light of the sun, which, when spread out, forms the visible spectrum, the sun sheds upon us a large amount of energy invisible as light. Professor Stokes's investigations have shown that this invisible energy, when passed through a prism of quartz, is spread out like light, and contains lines or spaces where this energy is absent, similar to the dark lines in the visible spectrum. By the substitution of a collodion plate for the eye, Professor Miller has investigated the invisible

Fig. 3.

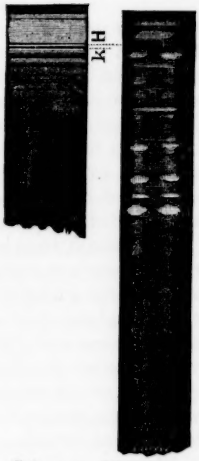

Fig. 4.

spectra of metallic flames. These are as distinct and characteristic of each metal as is the light spectrum of each. In Fig. 3 is given an engraving of the photographic impression of the invisible spectrum of silver, which is seen to extend many times the length of that portion of the visible spectrum which is actinic enough to record itself upon the plate.

Observation has shown that the length of these spectra of invisible energy and their lines are closely connected with the temperature of the source of heat. In Fig. 4 are given

representations of photographs of the refrangible portion of the solar spectrum, and of that of the metal magnesium. Though these have not been reduced to the same scale, the impression is a correct one, that that of magnesium extends much beyond the solar, and especially will it be noticed, is there a remarkably strong band in the magnesium spectrum just beyond the limits of the solar. Yet no metal has been proved to be present in the sun with more certainty than magnesium. Professor Miller regards this difference as an indication of the solar temperature. The magnesium spectrum was obtained by the electric spark. If, in place of this intensely high temperature, the oxyhydrogen flame of only 15°000 F. be substituted, the magnesium spectrum is shortened, and does not extend beyond that of the sun. From this Professor Miller infers that "the temperature of the sun may be approximately estimated to be not higher than that of the oxyhydrogen flame. It certainly appears to be far below that of the electric spark." This seems to be scarcely in accordance with the known law of the decrease of radiant heat. This decreasing, inversely as the square of the distance, gives an intense amount of heat to the solar surface. Waterston, in a communication to the Royal Astronomical Society in February, 1860, states that his experiments, founded upon the supposition that the difference between the temperature in the sun and the temperature in the shade, is a function of the sun's absolute temperature, give above "ten million degrees, probably twelve million, Fahrenheit," to the solar surface.

Is it not possible that vapours may exist in the solar atmosphere which, as Professor Miller shows to be the case with sulphuretted hydrogen, are but imperfectly diactinic, and so arrest these extreme rays of energy? Not that sulphuretted hydrogen, or any compound body, can be supposed to exist upon the solar surface. The elements there must stand too much aloof, by the mutual hate of the fierce heat, to unite themselves in alliances with each other. It may be, however, that conditions unknown to us alter or modify the terrestrial law of decrease of heat.

It seemed, however, an object of great interest to know if similar photographic spectra could be obtained of the stars. The writer and Dr. Miller have already been successful in photographing the more refrangible portion of the spectra of Sirius and Capella. The further prosecution of this investigation is necessarily deferred for the present.

"One star differeth from another star in glory, in wisdom hast Thou made them all."

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THE FEET OF HYMENOPTERA.

BY L. LANE CLARKE.

(*With a Tinted Plate.*)

It will be difficult to bring the feet of Hymenoptera within the compass of one paper, inasmuch as it is impossible, I think, to look at the claws and legs of these insects without consideration of the purposes for which they are modified and adapted, in the various species of this very numerous tribe.

We have now before us, besides our microscope, the mounted legs of bees, wasps, saw-flies, ichneumons, and ants; the first thing we notice is that the entire leg is composed of five joints, as in the Diptera, but with the *trochanter* divided into two parts, slightly articulated. The tarsal joints are invariably *five*, but differ considerably in length and in the form and number of their appendages. In fact, an intelligent observer will collect most interesting materials for his microscope by examining the legs of Hymenoptera, of which only a few are now figured to give an idea of their variety and strange forms.

Let not even the tiniest gall-fly or ichneumon escape notice, and if you are so fortunate as to possess a "binocular," the legs may be mounted dry on a disk of light green paper, when every spine and hair will be thrown up round and distinct under the deflected light.

For transmitted light, and the polarizing apparatus, these feet and legs must of course be mounted in balsam, and the legs of bees will require long soaking in potash, or a week at least of hydrochloric acid, to bleach them.

The hind leg of a bee is so well known with its basket and brush, that we need not do more than advise the mounting of the hollowed tibia, and the dilated first joint of the tarsi, edged with strong curved bristles, on the outer side of which is the collecting brush, having *ten rows* of *hairs*, and from sixteen to twenty-four hairs in each row (Fig. 1). But, having mounted the hive bee's leg, there will be a most interesting variety in those of the small humble bee, carder bee, and leaf-cutter bees (*Megachile*). The spines upon the tarsal joints, and the different arrangement of hairs in the brush, are worthy of attention. The pulvillus and claws of the hive bee should be taken from young ones just hatched, being more transparent then. The membranous sucker is folded up when at rest, and inflated into a cup-like disk, edged with adhesive hairs, when the foot is in action (Fig. 1).

Nor should the anterior legs be neglected, for they have in most bees a very curious *notch and spur*, unmentioned in popular bee-books. The hive bee has a deep notch on its fore tarsi, edged with short hairs, and above, on the extremity of the *tibia*, a moveable spur, strong and sharp, which forms a handy pair of pincers, and which I have seen used very effectively under certain circumstances (Fig. 2). When the honey-bees drag a dead intruder from the hive, they use their foot, jaws, or mandibles only; but when they fight a wasp, or expel a refractory drone, they use their fore-leg to clasp and hitch into that notch a leg of their opponent, neither drone nor wasp having the same useful appendage to make the fight an equal one.

In the fore-leg of the *Bombidæ*—humble-bees and carder-bees—the notch and spine are still more developed (Fig. 3). The spur has a strong sharp point, and a horny blade like a pocket-knife, the very thing these little workmen needed for hackling their moss, and building their cells.

The pretty spotted bee (*Melecta punctata*) which hovers over the bright furze blossoms from March to June, has a winged spine on its fore tibia, and the tarsi are beautifully pilose, as if silvered with delicate metallic hairs (Fig. 4); the claws are deeply toothed, the pulvillus very distinct, and mounted dry on a disk of blue paper it is a beautiful object for the binocular.

The leg of *Mesotrichiæ* (Fig. 5) is given merely as an example of variation, for which there is doubtless reason good in the habits of the bee. It is a South American insect, and builds in cavities near the summit of trees. The strange dilatation of the basal joint of its tarsi and curled tufts of hair, as well as the strong spine on the third joint, and triangular tufts of hair, are very remarkable.

The curious feet of *Dryinus cursor* (Fig. 6) are figured to show the position of claws and pulvillus. The fore tarsi have only a single claw, serrated and reflected backwards, whilst the pulvillus is inflated and porrected forwards. The hind tarsi have two small claws, much dilated at the base, and a very large pulvillus. The entire insect should be mounted in balsam. This small ichneumon may be taken from June to August; the females are apterous, the males look like winged ants running over the herbage.

The small ichneumon, *Smiera*, has most singularly curved tibia and tarsi (Fig. 7). This fly may be taken on the banks of ponds and quiet rivers, where it hovers watching for the larvæ of Strationidæ, in which it deposits its eggs. The *Stratiomys* is a black and yellow fly, which passes the first part of its existence as an aquatic larva, with a beautiful apparatus

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for breathing—a coronet of hairs terminating its body, which is spread out like a star on the surface of the water, and enables the insect to take in a full supply of air.

But it is in the family of the Fossorial Hymenoptera that the strangest form is found. The *Crabro cribrarius* has a dilatation of the fore tibiæ and tarsi into a concavo-convex plate, apparently soldered on these joints; it is pierced with small dots, each covered with a transparent membrane, which is capable of inflation and adhesion, probably for the same purpose as the sucker on the foot of the male *Dyticus* (Fig. 8). This insect haunts the umbelliferæ in July and August.

The *Ammophila campestris*, another of these burrowing wasps, besides some strong hooked claws, possesses a remarkable toothed spur at the lower end of the fore tibia, and the upper tarsal joint is edged with stout bristles (Fig. 9). Now I doubt not that these act as rakes, and also as grapples, for the work of this fossorial insect is by no means easy. I well remember lying under an apple tree at Woodlands one hot summer's day in July, my eye was attracted by a wonderful orange-coloured creature toiling across the gravel walk, dragging a fat grass-green caterpillar. I was a child then, and knew no scientific names; the romance of natural history was my delight, and so I watched the progress of this poor caterpillar in its enemy's jaws. The larva writhed, and twisted, and clung to every pebble on its way, and the fierce Ammophila tugged, and pulled, and got it along somehow, over the gravel, and on to the flower-bed beside me. Then it dropped the caterpillar, which only faintly tried to crawl away, and had not time to move an inch before back came the fly, which had removed a pellet of earth close by, and discovered a deep-looking hole. This was, doubtless, her nest, and seizing the caterpillar she began to back into the aperture; the fat grub was hard to manage, but the legs and feet of the *Sphex* were set firmly against the sides of the tunnel, these spurs erect, doubtless, and forming a strong finger or toe behind the tarsal joints, which gave her good help in the descent, for, more speedily than I could have believed, they both vanished from my sight. About two minutes elapsed, and the Ammophila re-appeared, quickly replaced its pellet, and concealed the aperture so effectually that I could not find it when, after watching the flight of the insect for a moment, I turned to examine the nest.

This Ammophila was not so obliging as the one observed by Ray in 1667, who, after building in and treading down the earth within its burrow, brought two fir leaves and marked the spot, which enabled him to investigate the contents of her excavation.

Feet of Hymenoptera.

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Amongst the Crabonides is a foot reversing all ordinary rules, belonging to the *Mellinus*, a sand wasp. Here the pulvillus is a large sucker on the *apex* of the claws (Fig. 10), instead of between them or under them. There is a reason good for this; the *Mellinus* provisions her nest with living flies, and a big blue-bottle by no means suffers himself to be quietly dragged into the dismal den where voracious young grubs await it; a fierce battle ensues, and even when so far overcome as to yield, and go struggling down, I can understand how useful to the Mellinus these suckers on the *knuckles* may be, in a difficult descent wrestling with its victim.

The legs of the tenthredo or saw-fly are easily mounted, being naturally transparent, and are particularly useful for examination of the joints; not only can the ball and socket between the tibia and tarsi be observed, but the muscular ligaments are often perfectly discernable in a well-mounted specimen (Fig. 11). The spurs, however, constitute its beauty, hanging in lobes from each joint of the tarsi. These little organs inosculate each in an appropriate socket, and have a degree of motion; they are also provided with a kind of sucker or pulvillus, which assists the insect in climbing and clinging to the twigs when the abdominal muscles are in full play during the preparation of its nest. Observe the position of its body upon an upright rose twig or gooseberry branch, the working of its saws with double-action blades, the whole frame quivering with exertion, and kept steady by these adhesive tarsi.

In May and June these saw-flies are common in every garden, and may be caught in the act of preparing the furrow from whence so many little hungry green larvæ will issue forth to desolate our fruit-trees.

Yet the Hymenoptera, as a class, are the ablest and best friends of man, and we may look gratefully as well as admiringly at the tiny feet. The honey-bee is an universal favourite; I never heard it maligned but once, when a crabbed old Cockney, who had retired to his country box, adjoining our residence, sent in a note requesting us to remove our bees, as they quite spoilt his (the Cockney's) flowers. But the rest of the tribe are not sufficiently appreciated, nor the immense importance of such avengers as the ichneumons and the *Sphecides* in keeping down hosts of caterpillars. What should we do with the larvæ of the *Pontia brassica* if we had not the busy little *Microgaster* to stop their increase with her own maternal instinct. These small caterpillars, like many others, eat daily twice their own weight of leaves, as if an ox, weighing sixty stone, were to devour every twenty-four hours three-quarters of a ton of grass; and when we remember that each of those innocent-looking white butterflies, flitting over the cabbage-bed,

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will deposit 1,600 eggs, we have reason to be grateful for the little friend whom God has sent to keep in check the voracious depredators; twenty-five out of every thirty caterpillars are destroyed by it. We all know the pest of our rose-trees, the little aphides, *one* of which in five generations is the progenitor of 5,904,900,000 descendants! These are followed persistently by the small ichneumon, *Aphidius avenæ*, and destroyed.

Does not the farmer tremble when in a July evening he sees the yellow *cecidomyia* hovering over the wheat ears? If he looked closer, he would see a small black ichneumon (*Platygaster*) following the track of the midge, and quietly dropping its own egg in the newly-hatched larvæ, which will stop further mischief for this time.

The clover-worm hides in vain in the legume of the plant, and the wire-worm in the earth. The hymenopterous enemy finds out the vulnerable spot, and saves us from our unseen and often unsuspected foe. *Pompilius* and *Pimpla manifestator* keep down spiders and various voracious grubs, whilst the much abused wasp rids us of innumerable flies.

THE PRECESSION OF THE EQUINOXES, AND APPARATUS FOR ITS IMITATION.

BY THOMAS W. BURR, F.R.A.S.

THE places of the fixed stars are necessarily designated by two co-ordinates, and those generally used are known as Right Ascension and Declination.

The former is the distance from a fixed point in the heavens, called the First Point of Aries, being one of the two places where the equinoctial and ecliptic cut one another; such distance being measured from west to east along the equinoctial, and reckoned either in 24 hours or 360 degrees. The two points of intersection of the circles called the ecliptic, or the sun's apparent path in the heavens, and the equinoctial, or earth's equator projected to the celestial vault, occur in the signs of the zodiac, Aries and Pisces; and the intersections or nodes mark the first points or beginnings of these signs. The nodes are also called the equinoxes, because when the sun is situate in either of them, the days and nights upon the earth are equal. The other co-ordinate Declination is the distance of a star from the equinoctial towards either the North or South Pole of the heavens, measured in degrees only, and is distinguished as north or south declination. It is, however, by many

astronomers, and in many catalogues of stars, replaced by North Polar Distance, in which the distance of a star is measured from the North Pole instead of the equinoctial, and carried over that circle to the South Pole. No declination can exceed 90°, but north polar distance may of course reach 180°. It will be seen that right ascension in the heavens answers to longitude upon the earth; while declination corresponds with latitude. It may here be noticed that there is a celestial longitude and a celestial latitude, which, however, are reckoned along and from the ecliptic instead of the equator, and therefore do not correspond to the terrestrial elements of the same names; but celestial latitudes and longitudes are only used for special purposes. These elements, right ascension and declination, having been in use for centuries to describe the positions of the stars, it becomes an interesting subject of inquiry to know whether the stars really retain the same precise positions when observed at different times; and although it is obvious that they preserve their *relative* places unchanged, the constellations presenting the same appearance to us as to the earliest observers, still it is found, as the result of the most delicate and careful observation, that the co-ordinates of the place of a fixed star do suffer some slight alterations from time to time, and modern astronomy has succeeded in proving the existence of four distinct corrections necessary to be applied to the observed places of stars, to reduce them to a standard right ascension and declination, or north polar distance. When these alterations are investigated, it is found that they are of two distinct kinds, and are in no case due to the motion of the stars themselves, but either depend upon real alteration of the position of the axis of the earth (upon which the observer is located), in space, or are purely optical in their character; so that the stars again become entitled to the appellation "fixed," which they seemed in danger of losing.* If we look a little closer into the matter, we shall find that there are two apparent motions of the stars due to optical causes. First, the effect of our atmosphere upon the stars and other heavenly bodies, called Refraction, which, by bending the rays of light coming from those luminaries, produces an apparent elevation of them above their real height from the horizon, and which varies with such altitude, amounting to more than half a degree at the horizon, a quantity equal to the diameter of the sun or moon, and thus causing them to be seen when they would otherwise be invisible to us; being only one minute at

* This general statement requires qualification in the cases of those stars proved to have what is called proper motion, but as the cause of this may probably be in most instances the motion of our sun and solar system in space, it has not been thought necessary to make the exception, beyond this note to show the point is not overlooked.

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45° of altitude, and diminishing to nothing at the zenith. The correction to be made for this elevation is obtained from tables of refraction, which give the deduction to be made from apparent altitudes, due to the stars' height and the varying state of the barometer and thermometer at the time of observation.

The second alteration of an optical character is that due to the effect known as the Aberration of Light, by which the rays proceeding from any heavenly body become disturbed in their passage, in proportion to the relative velocities of light and of the earth, to which such rays are travelling; and as these velocities are as 10,000 to 1, the result is that the light reaches us in the direction of the diagonal of a parallelogram, having sides of those proportionate lengths, and the stars are displaced about 20″ in different directions, as the earth travels in its orbit round the sun in a year, the apparent place describing a small ellipse round the real place. This apparent alteration is also readily eliminated by the proper correction; for the application of which directions are given in all astronomical catalogues.

The remaining two changes of place in the stars are much more important, and, forming the principal object of the present paper, will require greater detail in their treatment. They are called the Precession of the Equinoxes, and the Nutation of the Earth's Axis. Unlike refraction, which is a variable element, and aberration, which is constant in quantity, and completed annually in the small elliptical motion we have described, the motion affecting the places of the fixed stars, called precession, is constant in its character and accumulative in quantity, until completed in a cycle of enormous length. Its discovery took place more than 2000 years ago, by the celebrated Greek astronomer, Hipparchus, but the cause remained unknown till explained by the surpassing genius of Newton. Hipparchus, when ascertaining the place of the equinox at Alexandria, by observations of the time when the sun had no declination, found that the point so ascertained no longer corresponded with the place indicated by the still older observations of Aristillus and Timocharis, made 150 years before, but had shifted about 2° to the westward; and following up this discovery for thirty years, he found that the equinox moved westward about a degree in every seventy-five years, and he likewise found that this change involved a corresponding alteration in the places of the stars, whose right ascension being measured from the vernal equinox as a starting point, would necessarily have their distance from such point increased by the retrograde motion in question, as the earth in its rotation would have to turn further on its axis from the first point of Aries, before it had any particular star on the meridian (which indicated the

right ascension of that star), than it had to turn the year before, because in the year the first point of Aries had been shifted to the westward. This may be illustrated by supposing a road running east and west, and a carriage crossing it at a certain point; then the distances of all houses, churches, trees, or other objects to the east of that crossing, and measured from it, would be altered and increased if the carriage, after taking a sweep round, returned, and crossed the road at a place a little to the westward of its previous passage, although the relative distances between the objects themselves would remain the same. Notwithstanding the motion, being from east to west, contrary to the planetary motions in general, is really a retrograde one, it is called The Precession (or acceleration) of the Equinoxes, as, by carrying the node to meet the sun, it makes the equinox occur earlier than it otherwise would, and makes the solar year 20 minutes 22·9 seconds shorter than the sidereal one, the former being measured by the passage of the sun from one of the equinoxes, and the latter, by its journey from a particular star, till it arrives at the same equinox, or star.

The effect of precession, though small in each year, and altering the first point of Aries only 50″·3 annually, by its continuance produces great changes. Thus the signs of the zodiac (that is, the portions of 30° each into which it is divided, and through one of which the sun travels in a month), when originally named, coincided with the constellations of the same names, and the intersection of the ecliptic and equator, called the First Point of Aries, was really at the beginning of that constellation; but Hipparchus found that even in his time they no longer agreed, and in the two thousand years that have since passed, the difference has so accumulated that the signs and constellations of the same names are more than a sign, or 30° apart, and the first point of the sign Aries is in the constellation Pisces; the first point of Libra in the constellation Virgo, the tropic of Cancer in the constellation Gemini, and that of Capricorn among the stars of Sagittarius.

The fact was thus known and estimated, but the cause remained undiscovered until the grand generalization of gravitation was announced by Newton. He arrived at the theoretical conclusion that the earth was not a perfect sphere, but flattened at the poles, which subsequent accurate measures showed to be correct. The equatorial diameter is twenty-six miles greater than the polar, producing a ring or belt of matter thirteen miles high at the equator. Now as, according to the law of gravitation, every particle of matter in the universe attracts every other particle of matter, wherever situate, with a force directly proportioned to their mass, and varying inversely as the square of their distance; the sun and the moon, both

large masses of matter, and comparatively near the earth, act powerfully on it (the sun's attraction, in fact, keeping the earth in its orbit); but as there is more matter at the equator than elsewhere, and this projecting matter is nearer to the sun and moon than the matter at the centre of the earth, the projecting portion is more strongly attracted than the centre, and by its endeavour, in conformity with this attraction, to approach the sun and moon, tilts the equator a little out of its position, and this tilting, modified by the earth's rotation, causes a corresponding motion of the equinoctial points, which, being the places where the equator and ecliptic cut each other, must necessarily move if either of those circles shift its place. Nor is the motion of the equator the only one. This part of the earth cannot move without the rest of the globe. The earth's axis, which may be imagined as passing through it like a bar of iron from pole to pole, and stretching to its vanishing points in the heavens, must move too; and this effect also was early noticed, viz., that the place of the pole in the sky did move, and that it was clearly the direction of the pole that changed, and not the stars themselves. Precession, therefore, alters the declinations of stars as well as the right ascension. In some cases it increases this element, in others it diminishes it, the amount varying, but never exceeding, 21″ per annum. Thus, at the time of the earliest catalogues, our present pole star could not have fulfilled that office to the observers of that time, as the earth's pole pointed 12° away from it. The Pole Star, *a* Ursæ Minoris, is now only 1½° from the North Pole, and will approach to within half a degree of it, after which it will recede, and in twelve thousand years Vega *a* Lyræ will be the pole star, being then only 3° from the earth's pole; so, too, about four thousand years ago, *a* Draconis was the earth's north pole star, though now many degrees distant. If the path of the pole be traced out among the stars, it will be found that this extremity of the earth's axis moves in a circle of 23½° radius round the pole of the ecliptic, which extensive sweep is due entirely to the Precession of the Equinoxes. The rate of motion is very slow; it has taken two thousand years to move 33°, and will be about twenty-six thousand years (25,868) going completely round. The pole, like the equinoctial points, moves from east to west, contrary to both the earth's motions, orbital and axial. The precession of the equinoxes is intimately connected with the other motion to which we have alluded, as altering the places of the fixed stars, although not due to any real change of place in them, but to the motion of the axis of the earth on which the observer is placed, and which remaining motion is called the Nutation of the Earth's Axis. The alteration produced by it is very small indeed, and our knowledge of its existence is a

result of the delicate and masterly observations of Bradley, one of the greatest astronomers of modern times, to whom we are also indebted for the discovery and explanation of the aberration of light. Bradley was engaged in researches having for their object the discovery of the parallax of the stars, and hence their distance from the earth, and was working upon the star γ Draconis, which daily passes the zenith of London, and although disappointed in his original object, he observed such a motion of the star as led him to the discovery of nutation. To explain his observations, we must remind you that precession is due to the greater attraction which the sun and moon exert on the protuberant equatorial belt of the earth than they do upon its central portion, and upon the central part than upon the parts further off, and that this attraction, or pulling, which would be ineffective except as to tidal movements upon a sphere, when exercised upon a spheroid by the sun, when above or below the equator, has a tendency to pull the equatorial belt towards it, and thus bring the earth's axis more nearly perpendicular to the ecliptic; but this effect being modified by the earth's rotation on its axis, results in bringing the equator to meet the ecliptic at a point earlier than it otherwise would. Now it is obvious that this disturbing force of the sun must be greatest when it is at either of the solstices, or points of extreme distance from the equator, and nothing at all when the sun is at either of the equinoctial points, where the sun, being in a line with the equator, there would be no tendency to produce tilting of the earth's axis. Precession, therefore, goes on more rapidly in summer and winter than at other times, and this irregularity in its rate constitutes Solar Nutation. There is a similar small irregularity occurring every month, due to the varying position of the moon above and below the earth's equator, which is one part of Lunar Nutation, but the effect of both these causes is almost inappreciable, not exceeding an alteration of half a second of arc in each case.

The principal part of the nutation of the earth's axis, which is caused by the moon, occurs in this way :—The moon produces a much larger part of precession than the sun does, although the moon is so very much smaller than the sun, being equal to only $\frac{1}{20,000,000}$th part of the sun's mass. She is, however, 400 times nearer than the sun, and this makes her whole attraction, in proportion to her mass, 160,000 times as great as the sun's; still her whole attraction is only $\frac{1}{150}$th of that of the sun. But the important thing to be remarked in the explanation previously given is, that precession is not produced by the whole attraction of the sun or moon upon the earth, but by the difference between the attractions which they exert upon the earth's centre and upon the earth's nearest surface. For the moon,

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the proportion of the distance of these parts is nearly as 60 to 59, and then the difference of the attractions is about $\frac{1}{30}$th of the whole attraction of the moon. But, for the sun, the proportion of distances is nearly as 24,000 to 23,999, and then the difference of the attractions is about $\frac{1}{12,000}$th of the whole attraction of the sun.* The consequence is, that the difference of attractions of the moon is actually three times as great as that of the sun, and the precession produced by the moon is three times as great as that produced by the sun. Now the moon's orbit does not coincide with the ecliptic, but is inclined to it at an angle of 5°; and this orbit, from the disturbing effect of the sun's attraction, moves so that its nodes or intersections with the ecliptic travel entirely round in the space of nineteen years, preserving its constant inclination of 5°. The earth's equator is inclined to the ecliptic at a constant angle of $23\frac{1}{2}°$, and therefore the inclination of the moon's orbit to the earth's equator is constantly changing, and the moon's orbit is, for half the nineteen years, very little inclined to the earth's equator, and for the remaining half is very much inclined to it. In the former case, precession goes on very slowly, and in the latter very rapidly; and this irregularity in the rate constitutes the great part of lunar nutation. The tilting of the axis from side to side of its normal position is modified by the earth's rotation into motion in a small ellipse, having a major axis of 18″, which is completed in about nineteen years. Bradley, in fact, found that the star γ Draconis continued to move north of its proper place from 1727 to 1736, a motion totally inconsistent with parallax, which would have been complete in a year; and having formed his hypothesis of the cause, he continued his observations, and found the star then returned, and went south for nearly ten years, so that in 1748 he was enabled to announce his discovery of the nutation (or nodding) of the earth's axis. The effect of this nutation, if existing alone, would be the motion of the earth's pole in the small ellipse previously described; but, as precession is going on at the same time, and carrying the pole of the earth round the pole of the ecliptic in a circle of $23\frac{1}{2}°$ radius, the two motions become compounded, and the result is an undulation of the precession curve, the small ellipses of nutation never being completed, but the motion of the pole turned into an undulatory circle instead of a uniform sweep round the ecliptic pole.

As the precession of the equinoxes alters the places of the

* For these proportions, and the general idea of the treatment of the causes of the motions of precession and nutation, the author is indebted to Airy's Ipswich *Lectures on Astronomy*, a work which is unrivalled for the lucidity and completeness of its explanations, and is invaluable alike to both student and teacher.

stars so materially, it becomes necessary, in constructing catalogues and maps of the stars, to name the precise period or epoch at which they represent the places; and this is done by affixing the proper date of the catalogue or map to which all the observations have been reduced, and then by adding to the lists of the stars' right ascensions and declinations other columns showing the annual variation in these co-ordinates caused by precession, the place of each star can be calculated for any other time, either before or after the catalogue epoch.

From the preceding explanation of the motions of precession and nutation, which has been given in the simplest form possible, it will be seen that the subject is one presenting some difficulty in its conception to the non-mathematical student; and even with the aid of diagrams the difficulty is not readily obviated. It has therefore always been a desideratum to obtain for educational purposes some piece of mechanism which should imitate the motions in question, and render tangible that which had to be comprehended by the mental faculties. Accordingly, Bohnenberger, the late Professor Baden Powell, and others, have devised such pieces of apparatus, in which a conical motion of an inclined axis round a perpendicular was obtained, but an exact representation of the earth itself was not attempted.

About nine years since, the writer having occasion to explain these motions to a popular audience, contrived an apparatus for the purpose of illustration, which is admitted to imitate them perfectly, and which having been found extremely useful by him, and the limited circle to whom it has hitherto been known, is now made more generally public.*

Its conception was founded on two well-known data. First, it has long been known that the motions of a child's top in spinning afford an excellent illustration of the conical movement of the earth's axis in precession, although, from the force being opposite in character, the tendency there is to increase the distance between the axis of the top and the perpendicular to the horizon, while in the earth's case the tendency is to bring the axis of the earth nearer to the axis of the ecliptic; still the tilting force, modified by rotation, produces in the axis of the top while spinning a motion describing a cone round the perpendicular, preserving (until near the end of its spin) the same inclination; but in this case the motion is in the same direction as that of the rotation, instead of being the reverse, as in precession, and the analogy, therefore, here fails. The

* It has only been previously described and figured in the monthly Notices of the Royal Astronomical Society, vol. xv., and in Worms' excellent work, *The Earth and its Mechanism.*

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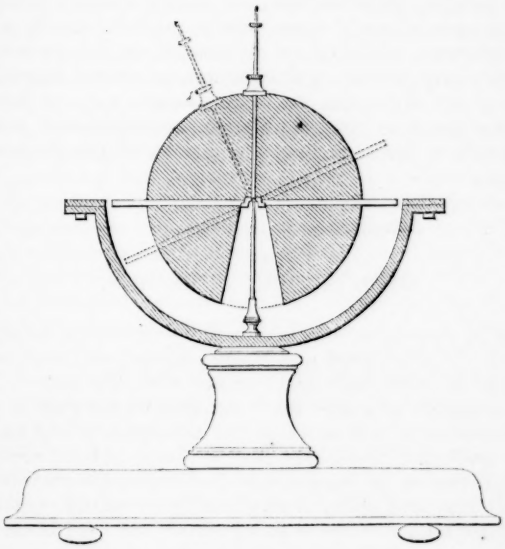
second principle of the author's apparatus, however, removes this difficulty. It had been shown by Mr. Atkinson, in the first volume of the monthly Notices of the Royal Astronomical Society, that by altering the position of the centre of gravity with respect to the point of suspension in a rotating disk, the conical motion could be made to coincide with, or be the reverse of, that of rotation. Guided by these principles, and adding such improvements as would more effectually represent the real motions of the earth, the apparatus shown in elevation and section by the accompanying engravings was constructed. It

PRECESSION APPARATUS, FIG. 1, ELEVATION.

consists of a small terrestrial globe, having a brass disk passing through the centre, and representing the equator projecting from the globe. The base of the globe is hollowed out, to allow its suspension on a point which rises in the interior to the level of a horizontal graduated circle, representing the ecliptic. Through the upper hemisphere runs a steel axis projecting above the North Pole, and terminating in a cup at the middle of the globe, which axis is capable of being raised and lowered by a screw motion in the brass socket at the

pole.* If now the axis be so adjusted that the point of suspension is above the equatorial disk, and consequently above the centre of gravity, and the globe be rotated rapidly from west to east, by winding a silk cord round the axis, and spinning it like a top, it will be seen that while the rotation from west to east on the axis imitates the diurnal motion of the earth, there is also generated a slow conical movement of the projecting axis round the pole of the horizontal circle, representing the ecliptic, in a direction opposite to that of the diurnal rotation, that is, from east to west; and that the equinoctial points or intersections of



PRECESSION APPARATUS, FIG. 2, SECTION.

the equator and ecliptic move slowly round in the same way. It is necessary that either a small weight should be attached to the equatorial disk, which may be done by putting a little piece of brass on a pin, or the equator may be made to preponderate a little on one side, or a simple inclination of the axis at starting will suffice to produce the precessional motion; but it is better to have the equator slightly weighted on one side, as in this case it is found that besides describing the circle representing precession, it will be seen that the projecting axis

* Mr. Hislop, of 108, St. John Street Road, constructs the apparatus.

performs a number of minute oscillations, or noddings, which render the principal curve undulatory in character, and give a perfect imitation of the nutation of the earth's axis, as well as of the precession of the equinoxes.

By carefully adjusting the distance between the point of suspension and centre of gravity, the rate of the motion can be adjusted to any desired proportion between it and the rotatory movement; and of course by lowering the centre of gravity, the directions of the two motions may be made to coincide as in the spinning top; while by getting the two points to meet at the same place, the tendency to conical motion is neutralized, and the rotating globe can then be carried round a central ball or lamp, representing the sun, with its axis constantly pointing in one direction, affording an illustration of the parallelism of the earth's axis, producing the phenomena of the seasons, thus rendering the apparatus useful in another way, as well as in its original purpose of exemplifying the mechanical principles which produce the important phenomena of the Precession of the Equinoxes.

MICROSCOPIC PURSUITS.*

THE highly successful efforts of many opticians in London and elsewhere, to make good and cheap microscopes, have supplied thousands of individuals and families with the means of perpetual recreation of a scientific kind, and we are glad to observe the publication of numerous works calculated to suit the wants and the pockets of those who may be disposed to let amusement and improvement go hand in hand. To gaze for a few moments at a well prepared slide, or at a small natural object, placed on the stage of a microscope, is an agreeable, but very transient and unsatisfactory employment, unless the observer knows the character and uses of the structure he sees; and hence there is no possibility of deriving permanent pleasure from such a source, without taking the trouble to become acquainted with at least the elements of many branches of knowledge. We recently heard a gentleman, who had carried off many prizes in his university career, complain "that the worst of the microscope was, that it required you to learn so much." This is one view of the question; but what, at first sight, appears an objection and a stumbling-block, must be seen upon considera-

* *Objects for the Microscope*; being a popular description of the Most Instructive and Beautiful Subjects for Exhibition, by L. Lane Clarke. Second edition. Groombridge and Sons.

tion to be the highest recommendation to the purchase and use of one of the most admirable instruments that optical art has contrived.

The difficulty of a beginner is not the extent of the subjects that open before him, but how to get at them at all. If money were of no consequence, and he started with fifty pounds' worth of the best books on natural history, botany, physiology, and so forth, his bewilderment would be increased, without his doubts and queries being solved. What is necessary to smooth over the early stages of any scientific pursuit is an elementary guide, suggesting a right method and giving a clear insight into the facts and principles that form the groundwork of the subject in hand. With the microscope there is the additional difficulty that no one branch of study will be properly appreciated without acquiring a rudimentary acquaintance with many more.

For the advanced microscopic student, or for any one who commences the pursuit with a good general knowledge of science, no better book could be desired than Dr. Carpenter's admirable work;* but that which constitutes its great merit for the class for whom it is intended, renders it for a time unsuitable for those whose beginnings must take a humbler form. For these—and their name is legion—the second edition of the little book entitled *Objects for the Microscope*, by L. Lane Clarke, comes admirably into the field. In the less elaborated state of the first edition it obtained well-deserved success, which will be repeated now that the work has assumed—without departing from its original simplicity—a completer form. The book is founded upon a series of objects, nearly all of which may be purchased of the opticians in the form of slides; but its utility is by no means confined to the description of microscopic preparations, as it will suggest to the beginner what may be sought for and collected in any situation, and what may be learnt from it when the microscope is employed. The information, conveyed in popular language, is for the most part amply sufficient for a first lesson, and after it has been pleasantly mastered, the student will find himself materially helped towards understanding the more complete descriptions in formal scientific works, which would be unintelligible if approached without such preliminary aid. The objects described range over a wide area. Three chapters are devoted to the vegetable kingdom, including one that treats of infusorial earths and desmids. Then the animal kingdom is considered in about a dozen chapters, discoursing on a great variety of insects, and the second part describes mollusca, zoophytes, etc., together with

* *The Microscope and its Revelations.* Churchill.

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anatomical injected preparations, which have been judiciously selected for popular use, and the whole winds up with a chapter on "Slides of Crystallization." The task thus undertaken has been ably performed. The book will assuredly answer the purpose of securing the interest of a wide range of readers and incipient observers, and tempt many youthful members of society from the pernicious habit of idling away their time. It will also prove an excellent help to those who have undertaken the work of education, and desire to include a knowledge of natural objects in their scheme. We have no hesitation in according to the author our emphatic commendation; but of course it was improbable that so many matters would be discussed without some errors creeping in. One of these we notice in the optical remarks at the beginning, where it is said "that the larger the angle (of aperture of objective) the greater are the number of rays admitted, and the more brilliantly the object is illuminated, *the greater consequently is the defining power.*"

The mistake is in the last words, the fact being that the angle of aperture may be too great in proportion to power, and then definition, except of very delicate surface markings, is actually impaired. No one, for example, would use a quarter-inch objective for general natural history purposes, which had an angular aperture of 150°, as its penetrating power is necessarily less than that of one having an aperture of 80° or 90°, and, consequently, it is only fitted for special use. Beginners also will find large-angled glasses far more troublesome to use than moderate ones, and for the binocular small angles are usually preferred. The chapter on Polyzoa also needs a little revision. It is too much to say that "almost all the Polyzoa have calcareous sheaths;" many are horny, or membranous, and some, like the alcyonidiadæ, fleshy and cartilaginous, while the pedicellinæ have no cells distinct from the skin. It might also lead to error to speak of these creatures as "strictly solitary individuals," "though always found in a mass." They are intimately connected, and, as we explained in vol. ii. p. 67, Dr. Fitz Müller has detected in one species what he terms a "colonial nervous system," which he believes the whole class possess.

In microscopic, as in other works, the value of associated labour is soon recognized, and we should recommend every one to persuade a few friends to join in the pursuit. A little society formed of two or three neighbours, who can unite in expeditions for collecting objects, and meet occasionally for the display and discussion of their captures and preparations, not only provides the means of passing many pleasant hours, but lightens the inevitable toil. The Manchester Scientific Students' Association, of which we have just received a Report, is a body con-

ceived in the spirit we recommend. Larger associations have no doubt their uses, but we especially recommend the multiplication of small friendly groups, and we strongly advise all bodies, big and little, which may be united for any scientific object, to endeavour to rescue mechanics' institutions and similar societies from the deplorable plight into which their lecture systems have been permitted to fall. Not to pass beyond our immediate purpose of encouraging microscopic pursuits, let any one consider what help would be afforded if, instead of time and money being wasted on scrap lectures, succeeding each other in "most admired disorder," the leading facts and principles of any branch of natural history could be taught and learnt. The microscopist will soon find that half a dozen lectures on comparative physiology would be invaluable, together with a similar number on zoological classification, and as many on plants. Information of this kind ought to be communicated each year, and brought up to date, in every town of ten thousand inhabitants, that has any pretence to civilization; nor need smaller localities entirely go without a proportionate supply. Parents complain that their girls grow up like empty vessels, and their boys turn dissipated, but they seldom reflect on the needless difficulties that are permitted to obstruct the rational use of their faculties, and on the very slender encouragement which most families give to intellectual pursuits.

NEW THEORIES AND FACTS OF HEAT.*

One of the evils that has resulted from paying too much attention to a class of men called "practical," has been to confuse the general mind as to the meaning of the term "theory." The "practical man," who is often narrow-minded and ignorant, exclaims, on hearing something which he does not understand, "that is all *theory*," thereby meaning guess-work, or fancy, unsupported by fact. The real difference between the so-called "practical man" and his superiors in knowledge is, not that he *does* more than they do, but that he has not, like them, the faculty of perceiving the connecting links which logically tie a whole group of facts together, and lead to the explanation of them all by reference to a common

* *Heat, Considered as a Mode of Motion:* Being a Course of Twelve Lectures delivered at the Royal Institution of Great Britain in the Season of 1862. By John Tyndall, F.R., and Professor of Natural Philosophy in the Royal Institution. Longman.—*Exposition Analytique et Expérimentale de la Théorie Méchanique de la Chaleur.* Par G. A. Hirn. Paris: Mallet-Bachelier.

law. So far from the "practical man" being right in his attempt to confuse *theory* with *hypothesis*, he is totally in error, as no explanation of phenomena would be called a *theory* by any sound scientific writer or thinker, unless it differed in certainty very materially from a mere *hypothesis*. We shall not stop to inquire into the advisability of restricting the term "theory" more closely than is usual among writers of authority; but we should fail at the outset of our remarks on the "Mechanical Theory of Heat," if we did not guard against the misconception that all theories are fancies which are of little certainty in comparison with facts. Investigators, who do not proceed at random, assume the existence of a particular property, or the probability of a certain explanation, in order to guide them in their researches, and they then proceed by observation and experiment to ascertain whether their hypothesis is right or wrong. If wrong, they abandon it; if it *seems* right, they endeavour to ascertain whether the apparent correctness is an accidental result, or one necessarily and uniformly arising from a fixed law. In the latter case, they embody the knowledge they have acquired in the shape of *theory*, which explains the group of facts they endeavoured to elucidate; and their theory is just as true as any isolated incident which the "practical man" might be able to see.

Distinguished writers sometimes use the term "theory" in another sense, as when it embodies an explanation that *may* be wrong, but *must* be true, if certain assumed facts should ultimately prove to have a positive existence; and, in this case, the theory differs widely from a mere conjecture, which might be wrong even if the facts assumed as its basis should be established by further research. When, however, we find theory confounded with hypothesis, we may be sure that the individuals so offending have not mastered the rudiments of scientific thought.

The preceding observations will prepare the mind for the investigation of the remarkable facts concerning heat which have been made known during the last few years, through the researches of distinguished men in England and on the Continent, amongst whom Dr. Joule deserves a foremost place. They will also explain the sense in which M. Hirn speaks, when he says, "It should be clear to all that this Mechanical Theory of Heat is not derived from any particular hypothesis as to the nature of heat; but, on the contrary, that every hypothesis ought to satisfy (or conform to) this theory."

In 1863, Mr. John Stuart Mill wrote, in his admirable dissertation on Logic, in reference to the then partially demonstrated speculations embodied in Mr. Grove's "Correlation of

the Physical Forces," that "to prove Mr. Grove's doctrine, heat should be capable of being converted into electricity, electricity into chemical action, chemical action into mechanical force, and mechanical force back again into the very same quantity of heat which was expended at the commencement of the series." Since these words were penned, an immense progress has been made in the collection of the kind of proof which Mr. Mill required, and we are now able to show that "whenever we employ mechanical force to produce a temporary modification in the condition of a body, a quantity of heat is produced proportional to the mechanical force expended;" and that, "for an equal quantity of mechanical force produced on one hand and expended on the other, precisely equal quantities of heat disappear and reappear, whatever may be the substances submitted to the experiment, and whatever may be the changes they undergo; provided always that these changes are only temporary." It also appears that "a given quantity of mechanical force, or work, is equivalent to a constant quantity of heat; and that there is thus a Mechanical Equivalent of Heat, and a Heat Equivalent of Mechanical Force."*

To render this series of facts intelligible, let it be remembered that employing mechanical force by rubbing two bodies together makes them hot, and the quicker and more violently they are rubbed—that is to say, the greater the quantity of mechanical force expended in a given time, the hotter they will become; so that, as many savage tribes know, a fire may be kindled by the sufficient friction of two bits of wood. Here we have an illustration of the production of heat by mechanical force, and it can be shown experimentally that the quantity of heat obtained is always in proportion to the quantity of mechanical force expended in the process. Let us now take an opposite case—that of expending heat and obtaining an equivalent of mechanical work. First, we will consider the internal work done by heat among the atoms of a substance that is made hot. All its particles are moved, and under ordinary circumstances the body is expanded. Professor Tyndall tells us, "The energy of the forces engaged in this atomic motion and interior work is enormous. . . . . A pound of iron, on being heated from 32° to 212°, expands by about $\frac{1}{800}$th of the volume which it possesses at 32°. Its augmentation of volume would certainly escape the most acute eye; still, to give its atoms the motion corresponding to this augmentation of temperature, and to shift them through the small space indicated, an amount of heat is required which would raise about eight ons one foot high!" It is well known that expending heat upon

* Hirn, p. 20.

various bodies does not make them hot in the same proportion. A certain quantity of heat disappears, and used to be called "latent," or hid—a phrase that must now be changed, because we now know that it is consumed in the performance of interior work, altering the position of particles, or forcing them asunder, or both, as the case may be. Water has, for example, thirty times the so-called capacity for heat that mercury possesses; so that a given amount of friction, or mechanical force, only raises water to $\frac{1}{30}$th of the temperature to which it raises mercury. Dr. Joule took this and similar instances into his calculation, and when due allowance was made for the heat which thus disappeared, he found "that the absolute amount of heat generated by the same expenditure of power was in all cases the same."*

Friction is a retardation of motion, and heat is produced in proportion to the quantity of motion thus stopped. Bearing in mind that mechanical stoppage of motion produces heat, we shall be prepared to find that when a target stops a rifle or cannon ball, both ball and target are made hot; and in a smaller degree, because the amount of arrested motion is less, when a weight falls to the ground from a moderate height, the ground and weight are heated in proportion to the velocity of the fall. If the fall of the weight—a cannon-ball, for example—were from a great height, so that its accelerated velocity equalled that of a similar cannon-ball fired from a gun, an equal heating effect would be obtained. Now Dr. Joule ascertained that "the quantity of heat which would raise one pound of water one degree Fahrenheit in temperature is exactly equal to what would be generated if a pound weight, after having fallen from a height of 772 feet, had its moving force destroyed by collision with the earth. Conversely, the amount of heat necessary to raise a pound of water one degree in temperature would, if applied mechanically, be competent to raise a pound weight 772 feet high, or raise 772 pounds one foot high."† Thus, the mechanical equivalent of heat is obtained, and, for convenience in England, we calculate it from the quantity of heat which will raise one pound of water one degree of Fahrenheit's scale; though, while we do so, we regret that our pound is not like the decimal measures of our neighbours, a rational quantity, and that our thermometers are graduated according to an inconvenient scale.

The velocity of bodies falling to the earth is known to augment as the height from which they fall is increased, but not in simple proportion. "If the height be augmented four-fold, the velocity is only augmented two-fold; and if the height be

* Tyndall, p. 39. † Tyndall, pp. 39, 40.

increased sixteen-fold, the velocity is only augmented four-fold; but the heat generated by the collision of a falling body increases simply as the height, and consequently as the square of the velocity." Thus trebling the velocity will yield, on arrest of the motion, nine times the heat. Every one knows that when the break is applied to the wheel of the railway carriage, the stoppage of motion is accompanied by a great evolution of heat; and as the weight of the earth is enormously greater than that of a railway wheel and train, and its velocity of rotation immensely quicker, a similar arrest of our globe would give rise to a far intenser heat; so that, as Mayer and Helmholz have calculated, it would not only be melted, but a large portion of it would actually be converted into vapour.

Shooting at a target warms the ball which strikes, and the target which is struck. Motion is arrested, and an equivalent quantity of heat evolved. From this analogy, it struck Mayer, in 1848, that the sun might have the heat which he gives out restored, by the collision of bodies of sufficient size, shot at him with sufficient force; and the same idea has been worked out in this country by Professor William Thompson and others. Bodies are said to give out heat by radiation; that is to say, they excite a motion in the particles of adjacent bodies which tends to raise their temperature. Radiation into space is probably nothing more than exciting this motion in the highly attenuated matter with which it seems to be filled. So long as the Newtonian hypothesis, that radiant heat consisted in the actual emission of particles shot out in all directions from the radiating body, was admitted, the phrase, *giving out heat*, had a distinct and intelligible meaning; but now that this supposition is generally abandoned, we cannot consider radiating bodies as actual losers of any substance called heat, but simply as changing their mode of action as they grow cold. While they are hot they can excite heat in other bodies by a radiating process under which they themselves grow cooler and cooler, unless they experience a counter-action of a similar or different kind by which their heat is restored. Our sun, shining day by day, must, in accordance with this law, grow cold in time, unless his own heat receives continual additions equal to the amount of his loss. It is assumed—perhaps without sufficient warrant—that the sun is hot because he is the cause of heat in other bodies; and it is certain that if his giant orb follows the law that rules the radiation of caloric, he must be constantly losing the capacity of warming, and thus keeping alive, his portion of the universe, unless his heat-giving power is renewed as fast as it disappears, through taking some other form. Very slow would be the so-called dissipation of his heat; all the future generations of man might pass away, our

globe might change and change again in the arrangement of its materials and the nature of its climate, while its fellow wanderers through the realms of space might pass through alterations no less important—there might be time, and ample time, for modifications so vast to take place; but, however remote the final period might be, "The sun himself must die," unless his life experiences constant renovation, as well as suffers continual decay.

That nothing is constant, that all things change, is a sentiment conformable to our reason and experience, and we could raise no argument why in the eternal flux of ages the materials of suns and planets should not be re-arranged. No one can, therefore, feel any obligation to search out causes why the permanence of the universe should consist in anything other than the conservation of all forces of which it is composed. Still, whatever may be the ultimate destiny of the globe which we inhabit, or of the gigantic sun, an infinitesimal portion of whose energy is the source of by far the greater part of the vital and physical work done upon our earth, we can surmise no date for the termination of his labours, nor conceive *when* the period will come in which the system of compensations that we trace on all sides will fail to maintain the stability of our system, and we are, therefore, justified in looking for agencies whose operation will renovate that solar power on which its existence depends. We are only beginning to form some faint conception of the relation which our sun and his dependent worlds may bear to other and remoter celestial bodies. Analogy would lead us to suppose that our system has no independent existence, but forms part of a boundless whole, every portion of which, governed by some ultimate law, is undergoing incessant and harmonious change. There is, therefore, no improbability that our sun should continually receive new matter from realms beyond his own; and if meteoric bodies came within the sphere of his attractive force, and dashed through his atmosphere with velocities so great that the swiftest cannon ball, compared to them, would appear at rest, there can be no doubt an immense evolution of heat must occur. Before, however, we accept this hypothesis of how the sun's heat might be maintained, we must consider all the facts that have to be explained, and what consequences would result from the meteoric bombardment which many are so ready to assume, although there is yet no proof that it takes place.

The attempt to apply the mechanical theory of heat to the restoration of solar power, and the speculations of Kirchhoff, Bunsen, and others, on the constitution of the sun, as rendered more or less probable by spectrum analysis, offer a very wide field, both for reasoning and conjecture; and every student of

science should distinguish between the ascertained facts, or the certain inductions to which they lead, and those daring conceptions which may be the precursors of brilliant discoveries, or which may perish as knowledge advances and certainty is attained.

Whatever may be the fate of ingenious hypotheses, the facts embodied in the mechanical theory of heat will constitute one of the grandest additions to the science of our age. It suggests much new matter to be acquired, but it leaves no doubt of the truth of the magnificent generalizations embodied in such phrases as the "correlation and conservation of force," and we cannot present to our readers a nobler representation of the new philosophy than is contained in the words of Professor Tyndall, who exclaims:—

"The natural philosopher of to-day may dwell amid conceptions which beggar those of Milton. So great and grand are they, that in the contemplation of them a certain force of character is requisite to preserve us from bewilderment. Look at the integral energies of our world—the stored power of our coal fields, our winds and rivers; our fleets, armies and guns. What are they? They are all generated by a portion of the sun's energy, which does not amount to $\frac{1}{2,300,000,000}$ of the whole! This, in fact, is the entire portion of the sun's force intercepted by the earth, and in reality we convert but a small portion of this fraction into mechanical energy. Multiplying all our powers by millions of millions, we do not reach the sun's expenditure. And still, notwithstanding this enormous drain, in the lapse of human history we are unable to detect a diminution of his store. Measured by our largest terrestrial standards, such a reservoir of power is infinite; but it is our privilege to rise above these standards, and to regard the sun himself as a speck in infinite extension—a mere drop in the universal sea. We analyse the space in which he is immersed, and which is the vehicle of his power. We pass to other systems and other suns, each pouring forth energy like our own, but still without infringement of the law, which reveals immutability in the midst of change, which recognizes incessant transference and conversion, but neither find gain nor loss. This law generalizes the aphorism of Solomon, that there is nothing new under the sun, by teaching us to detect everywhere under its infinite variety of appearances, the same primeval force. To nature nothing can be added; from nature nothing can be taken away; the source of her energies is constant, and the utmost man can do in the pursuit of physical truth, or in the application of physical knowledge, is to shift the constituents of the never-varying total, and out of one of them to form another. The law of conservation rigidly excludes both creation and annihilation. Waves may change to ripples, and ripples to waves; magnitude may be substituted for number, and number for magnitude; asteroids may aggregate to suns, suns may revolve themselves into floræ and faunæ, and floræ and faunæ melt in air—the flux of power is eternally the same. It rolls in music

through the ages, and all terrestrial energy, the manifestations of life, as well as the display of phenomena, are but the modulations of its rhythm."

The volume of M. Hirn, and the admirable lectures of Professor Tyndall—which we cannot too strongly commend as one of the ablest efforts to make a difficult subject interesting and intelligible—would supply themes for fifty articles, but we shall only advert to one more topic—the action of vapours in absorbing heat. Mr. Tyndall has contrived an admirable series of experiments, which throw much novel light on the influence which gases, vapours, and the infinitesimal doses of matter diffused by odoriferous substances in the condition of perfume, exert upon heat; but none of his results are more striking than those which refer to the aqueous vapour held in solution in our atmospheric air. Repeated trials made with extreme care show that "the aqueous vapour of air from various localities,* examined in the usual way, exerted an absorption seventy times that of the air in which the vapour was diffused." In other experiments the air of the laboratory at the Royal Institution was dried and purified until its power of absorbing radiant heat fell below unity. It was then led through a U-shaped tube, filled with perfectly clean fragments of glass, moistened with distilled water, from which it absorbed water vapour, and when this vapour was carried into the experimental tube to test its heat-absorbing power, it was found "ninety times greater than that of the air which carried it." The absorptive power of humid air varies with its tension or density, being only sixteen when balanced by five inches of mercury, and as much as ninety-eight at thirty inches, which corresponds with the point marked "Fair" in common barometers. This property of aqueous vapour plays an important part in determining the climate of our globe, and rendering possible its various kinds of animal or vegetable life. "Regarding the earth as a source of heat," says Professor Tyndall, "no doubt at least ten per cent. of its heat is intercepted within ten feet of its surface." Were our atmosphere perfectly dry, the extremes of temperature would be excessive. The sun would burn us during his appearance above our horizon, and when his influence was withdrawn the loss of warmth would be violent and rapid. "The removal for a single summer night of the aqueous vapour from the atmosphere of England would," as Professor Tyndall tells us, "be attended by the destruction of every plant which a freezing temperature could kill," and our earth would soon be approximated to the condition of the moon,

* The localities are mentioned in the original—viz., Hyde Park, Primrose Hill, Hampstead Heath, Epsom Downs, Newport, I. W., St. Katherine's Downs, I. W., and Black Gang Chine.

which—so far as the side we see is concerned—possesses no moisture nor appreciable atmosphere, and is supposed by Sir John Herschel to fluctuate between a boiling temperature and a frost 220 degrees below the zero of Fahrenheit's scale.

Water vapour, as a great absorber of caloric, enables our atmosphere to grow warm, and thus we live in an agreeably diffused heat, while on mountain tops, where the air is very dry, and the solar rays strike with comparatively undiminished force, severe extremes of heat and cold are felt, according as the traveller passes in or out of the shade which rocky masses may afford. The effects of these discoveries of the action of water vapour cannot fail to be considerable upon meteorology, as it offers the true explanation of many phenomenon that have hitherto puzzled investigators. "Imagine," says Professor Tyndall, "a column of saturated air ascending from the equatorial ocean; for a time the vapour entangled in this air is surrounded by air almost fully saturated. Its vapour radiates, but it radiates into vapour, and the vapour into it. To the radiation from any vapour a screen of the same vapour is particularly opaque. Hence for a time the radiation from our ascending column is intercepted, and in great part returned by the surrounding vapour; condensation under such circumstances cannot occur. But the quantity of aqueous vapour in the air diminishes speedily as we ascend; the decrement of tension, as proved by the observations of Hooker, Strachey, and Welsh, is much more speedy than that of the air; and finally our vaporous column finds itself elevated beyond the protecting screen which, during the first portion of its ascent, was spread out above it. It is now in the presence of pure space, and into space it pours its heat without stoppage or requital. To the loss of heat thus endured, the condensation of the vapour and its torrential descent to the earth must certainly in part be ascribed."

Very dry climates will necessarily be more extreme in their changes than those in which the air is moist; and when foreigners from a less humid region, complain of the fluctuations in our weather, we may remind them that however they may pretend to the contrary, they are exposed to more striking vicissitudes. "In Sahara, where the soil is fire and the wind is flame," we are reminded by Professor Tyndal that the cold during the night is often painful to bear; and even in more moderate regions, where the air is dry, the transition is still severe. To our moist skies we owe the delicious green of English landscapes, which is not less beautiful because few artists have enough skill to use it wisely in their paintings, nor because the inhabitants of other countries are preferentially impressed by other hues. To our moist skies we also owe the beautiful com-

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plexions of our women, which we should be sorry to exchange for the various gradations of orange, tawny, brown, and black, which so-called better climates produce. Nor must vapour be supposed to have any necessary association with turbid skies. It is when undergoing precipitation that it disturbs the clear deep blue. When in solution it improves the colour of the atmosphere, and leaves distinct the vision of terrestrial objects, or of the moon and stars. Surrounded by vapour from the waters of the Mediterranean, M. Lassell works his great telescope with admirable effect. The air is *dry* because there is heat enough to prevent the precipitation and wetting action of the water vapour, but it is far from dry in the sense of being in a waterless state.

We may regard all bodies as giving out and receiving heat; or, in other words, as receiving and giving an incitement to a particular kind of motion of their particles. "When the sum of motion received is greater than that given out, warming is the consequence; when the sum of motion given out is greater than that received, chilling takes place."* Some bodies allow heat to pass through them readily, others obstruct its course. Some allow it to pass in company with light, others are indifferent to its darkness or luminosity; and the power of acting upon heat is not proportioned to the bulk of the intervening substances, but to their activity or energy. Thus if the absorbing power of air at the ordinary pressure be taken as unity, that of the vapour given off by the perfume patchouli is 30, of lavender 60, and of aniseed 372. "It would be idle," observes the Professor, "to speculate on the quantities of matter implicated in these results. Probably they would have to be multiplied by millions to bring them up to the tension of ordinary air." Thus while on one hand we see heat exerting powers which rend the most solid rocks, and tear the strongest metals, on the other we find its course arrested by a medium so attenuated as a perfume, which a substance could give off for indefinite periods, without sensible loss of weight. What heat may be, in its essence, we know not, nor can we understand why the motions of any particles should yield so wonderful a result. We have no knowledge of matter apart from force, and we recognize heat as one of the great forces of the universe, all of which our philosophy anticipates will be ultimately referable to one force, in which we shall see the eternal supremacy of mind.

* Tyndall, p. 260.

COMETARY PHENOMENA.

BY THE REV. T. W. WEBB, M.A., F.R.A.S.

THE well-known director of the Observatory of Athens, Herr J. F. Julius Schmidt, has published, in No. 1395 of the *Astronomische Nachrichten*, some curious remarks upon the large comet of last autumn, an abstract of which may be found interesting to many of our readers. The extraordinary clearness of the Athenian sky, which was interrupted by clouds on two or three evenings only between August 9 and September 26, enabled him to obtain such a continuous set of observations as could be equalled, or even approached, in few European observatories; and his results hence possess a special value. The coma he considered more circular and better defined than that of any comet which he had previously observed, and he illustrates the contrast of its outline with that of the narrow base of the tail at its origin, by comparing it to the form of an onion. The light of the nucleus varied greatly in intensity; on two occasions the change on successive evenings amounting to no less than 4 star-magnitudes; a difference, as he says, quite beyond the limits of error with a practised observer, especially intent upon such researches for years; and the observations of twenty nights led him to infer a periodical variation in about 2·7 days; but with rather a large proportion of uncertainty, averaging more than 0·25 of a day. The general *minimum* of light occurred a little after the perihelion; with the *maximum* intensity was connected either the narrowest form of the luminous jet or fan, or in its stead the bright diffused light attending the secondary jet (*mit dem Nebenfächer*); its enfeebled condition was attended by the largest, faintest, and curved form of that appendage. A libration, or apparent swinging, of the luminous jet as compared with the direction of the *radius vector*, or line joining the sun and the comet, was obvious. Without entering into the question whether it may have been one and the same jet, or a succession of them, which was subject to this reciprocation during about 2·7 days, Schmidt found such a period well-marked, with somewhat less uncertainty than that of the variation of light. The angles contained by the position of the jet and the axis of the tail varied from 249°·5 on Aug. 21, to 108°·1 on Sept. 6, with repeated and speedy fluctuations; the extent increasing to the time of the perihelion, and afterwards diminishing. On Sept. 15 a powerful jet was found to have commenced in an opposite direction to the one previously observed; of this he

gives us no further particulars, but he has promised a fuller memoir, with diagrams, which, it may be fairly expected, will prove very valuable. His final results are, for the period of the variation of the nucleus, 2·7 days; for the libration of the jet, 2·74 days; for the return of similar forms of the tail and the jet, 2·82 and 2·99 days respectively; but the two latter quantities have little claim to accuracy. He adds that the rapidity of the emission of luminous particles towards the sun amounted, by an approximate calculation, in the case of Donati's comet, to 371 *toises* in one second; in Comet II., 1861, to 252 *toises*, and in Comet II., 1862, to 230 *toises*, in the same period of time.

A comparison of these remarks with those of M. Chacornac at Paris, in No. 9 of the INTELLECTUAL OBSERVER, will be found interesting. The latter astronomer considers it an established fact that a succession of jets were detached from the nucleus in varying directions; inferring that the movement of libration could only have been a deception arising from the spectator's not having watched the progress of the phenomenon with sufficient continuity. The observations of Secchi at Rome are strongly confirmatory of the same view. He speaks of "luminous sheaves (*gerbes*) which were darted out by the nucleus, sometimes in one direction, sometimes in another, the two chief of which pointed, the one towards the sun, the second 45° from the first. These two directions, referred to the line joining the sun and the comet, have been almost constant, which proves two sufficiently fixed foci of eruption in the star. Their direction, however, deviated sensibly from the direction of the sun after the perihelion passage, which constitutes a theoretically interesting circumstance. * * * The most curious fact appears to me to be that of the intermittence of these jets. There has been such a periodicity, that we had at first suspected a rotation of the star around an axis as the means of explaining it, but having followed it during long nights, we have not been able to recognize any progressive variation explicable in this way; on the contrary, we have been present at the extinction and formation of luminous sheaves. Aug. 28, at 8h., the nucleus was without any protuberance, and round like a little planet; at 10h. 45m. it had already a decided prolongation; the nebulosity on the right side had the form of a curved cloud suspended and detached from the nucleus. These facts in their simplicity show that when there are several contemporary centres of eruption, a great number of jets may be simultaneously produced, and become the source of the luminous fans which have so frequently been observed in these stars." All this seems quite satisfactory; still it remains a well-established fact that an actual libration, or swinging

motion, was perceived and followed by Bessel during the last appearance of Halley's Comet in 1835.

The great difficulty which confronts us in every attempt to investigate the nature of these most strange visitants is the absence of all satisfactory analogy. No one could have watched the late opposition of Mars without being convinced of a general similarity between the constitution of that globe and our own; and even in Jupiter and Saturn, though belonging to another planetary type, the evident and complete control of gravity, the provision for day and night, and the existence of an atmosphere of varying transparency and constant mobility, form points of contact, so to speak, of considerable significance. But in the case of comets, with the sole exception of the influence of gravity over the denser portions of the mass, analogy breaks down altogether, and direct observation has hitherto for the most part brought out nothing more than a series of marvellous and unaccountable facts, maintaining obstinately the secret of the law, which no doubt unites them into a harmonious and beautiful whole. We have not as yet any adequate information as to the composition of the nucleus; whether, even in the most brilliant comets, it ever attains a state of actual solidity, or whether all may not be as unsubstantial as one of our own clouds, which at an equal distance and under suitable illumination would no doubt reflect a very vivid light: in fact, as to the real nature of the material of comets, beyond that extraordinary attenuation of mass which makes their attraction imperceptible, even in their closest known appulses to other bodies, we have not a single idea. That they are ponderable is certain, or they would not obey the attraction of the sun; but when we would trace their effect upon the balance of our system, we entirely fail. It appears from the experiments of Secchi upon the late comet with the polariscope, that the light of the nucleus and the brighter part of the "aigrettes" or jets, was never polarized, excepting very feebly on the last day of possible observation, while that of the surrounding nebulosity was strongly so, and the extremities of the jets exhibited an intermediate condition. But even this very interesting result, confirmed to a great extent by that of the great comet of 1861, in which the same observer found the polarization of the light of the tail and the rays near the nucleus very powerful, but no trace of it in the nucleus till July 3 and the following days, when it was strongly indicated, gives no distinct intimation as to the nature of the light. Secchi thinks that the condition of the nucleus may have resembled that of terrestrial clouds, which have no polarising effect, while the coma and tail may have been in a gaseous state; but it is obvious on how slight a foundation such a conjecture as to a

totally unknown material is raised: and though this great and justly-celebrated observer says that if we continue to make as much progress with future comets as we have done with the last three conspicuous ones, our knowledge of their nature will be speedily complete, one cannot help thinking that "the wish was father to the thought." In fact, there would be no greater difficulty in maintaining the converse proposition, that we shall never obtain any satisfactory idea as to their composition, unless we should get actually involved in their extent. There was, indeed, reason to suppose that the edge of the tail swept over us in 1861, but from the imperceptible passage of those very attenuated streams it would be hazardous to infer the results of immediate contact with a glowing nucleus. Up to the present time, the simple question cannot be considered to be decided, whether comets shine by native or reflected light, or by a combination of both; even forms which have been considered to be of constant occurrence, such as the curvature of the tail backwards from the direction of its motion, and the superior density and distinctness of its convex edge, have been shown by the recent comet to be less universal than had been supposed.* Few, indeed, are the points which we can consider adequately established. From the fixity, or limited movement of the jets issuing from it, it may be considered certain that the nucleus does not revolve;† a rotatory motion of the whole tail round its axis has indeed been suspected, from the reciprocating form of its branches in 1769, 1811, and 1825, and thought not impossible by Secchi in 1860: but even should this be admitted in some instances, in others it would be quite incompatible with observation.

It is evident that the whole mass is vehemently acted upon by some influence emanating from the sun, the continuation and accumulation of which, after the perihelion passage, seems to point to a calorific rather than a more instantaneous electric or magnetic action; and it would appear as though the nucleus, even if translucent to light, and reflecting it alike, as Sir J. Herschel suggests, from its interior part and from its surface, and therefore having no shadow or dark side, were not equally permeable by that solar influence, whatever it may be, since the

* The great comet of 1861 might also have been cited; but the direction of its perspective presentation to the eye rendered some of the results precarious and uncertain. The main tail of "the Donati" was strongly curved, yet a feeble ray which preceded it, like a lance borne in front of a streaming banner, though extremely faint, was sensibly straight, and this had been anticipated by similar phenomena in 1807.

† Secchi seems to have entertained an opposite opinion in 1861:—"L'examen de la direction des jets de lumière de la tête nous prouve que la tête avait un mouvement lent de rotation." But, as we have seen, he was unable to establish this, from similar appearances, in 1862.

formation of fans and envelopes takes place only on the side exposed to the sun, while the averse side is comparatively undisturbed, and as it were in a sheltered state. An intermittent or discontinuous process of development is frequently conspicuous, even when no regular period can be established; this was made very evident in succession of envelopes raised from the nucleus of Donati's comet, as described by several observers, and more especially by Bond in his admirable monograph; it was again manifest in the marvellous alternations of brightness exhibited by Comet III. 1860; and, as we have seen, reappeared strikingly in the aspect of our recent visitant. As remote as most of these phenomena are from all our terrestrial analogies, a still wider deviation is to be found in the tendency of cometary matter to repulsion, expansion, and ultimate dispersion. In the formation of the jets and envelopes, in the emission of the tail, in its irreclaimable projection to uncontrolled distances, and in the actual disruption of the main mass —to which there seemed a slight tendency in "the Donati," more in III. 1860, still more in I. 1860, and of which Biela's comet in 1846 appeared to offer a perfect example—we see indications of a process very foreign to our own experience, but remarkably characteristic of cometary matter. This brief and imperfect enumeration of some of the points, which we may look upon as "vantage ground" in such inquiries—in connection with the valuable remarks in the Hon. Mrs. Ward's paper in No. 9 of the INTELLECTUAL OBSERVER—may be useful in assisting amateurs to prepare for the next opportunity of further research, which, though it may be expected to confirm some of these deductions, may probably at the same time surprise us with unforeseen anomalies; for it is an interesting fact that as there is a broad family likeness, so to speak, among the whole class, so each individual (of any considerable magnitude) is apt to be distinguished by such peculiarities as infer most curious variations in composition; even in the same individual, diversities of colour, or want of symmetry in form, give rise to the idea of a combination of various materials, all, to us, equally unknown. What can more strongly impress upon our minds the extent of our own ignorance, or the vastness and complexity of the work of the great Creator!

TRANSITS OF JUPITER'S SATELLITES.

June 2nd. III. enters the disc at 10h. 37m. 5th. The shadow of I. enters at 10h. 9m., the satellite being on the disc; the egress of the latter is at 11h. 19m., of the shadow at 12h. 22m. 12th. I. enters at 10h. 56m., its shadow at 12h. 4m. 13th. The shadow of II. goes off at 11h. 31m. 20th. II. leaves the disc at 11h. 40m., 3m. after the entrance of its

shadow—so great is the obliquity now resulting from the position of the planet relatively to the Sun. 21st. I. passes off at 9h. 29m., its shadow not till 10h. 41m. 28th. The shadow of I. enters at 10h. 24m.

OCCULTATIONS.

June 3rd. ξ^1 Sagittarii, 6 mag., from 11h. 40m. till 12h. 46m. at Greenwich. 5th. 8 Aquarii, 6 mag., from 12h. 46m. till 13h. 54m.

THE NEW $\frac{1}{20}$TH MICROSCOPE OBJECTIVE.

In our brief notice of the *soirée* given by the Microscopic Society we mentioned the fact that Messrs. Smith, Beck, and Beck had exhibited a new $\frac{1}{20}$-inch objective, which appeared to be good; but the circumstances under which it was shown precluded our forming an accurate idea of its merits. Since then we have had one in our possession, and given it many trials, which enable us to speak of it in terms of the highest praise.

We have not enough respect for the recondite markings of troublesome diatoms to esteem very highly a glass which will show them, but do no more serviceable work. Our idea of a high power objective is that it should be equal not only to extraordinary emergencies, but take its place amongst the everyday working machinery which the microscopist naturalist is obliged to employ. Large angles of aperture will enable glasses to exhibit surface markings on diatoms, without their possessing a very high degree of excellence in other respects, and such instruments fail when applied to most of the inquiries by which science is really advanced. There is a due proportion between angular aperture and focal distance, which no doubt admits of theoretical demonstration, and which is approximately discovered in practical work. We do not know that the formulæ have ever been accurately computed, but it is certain that optical skill has made objectives in which the angular aperture has been largely in excess of penetrating power. To our apprehension no glass deserves real commendation unless it possesses all the characteristics which the rational use of a microscope requires. The angle of aperture should be duly proportioned to the focal distance, and the penetrating power should not be sacrificed to any other consideration. This penetrating power, without which no glass can be of general use, depends upon the perfection of the corrections for spherical and chromatic aberration, and upon the due propor-

tioning of angular aperture to focal length. It may, indeed, be possessed by glasses of small angular apertures, but they are then deficient in light, and do not show surface markings as perfectly as ordinary requirements demand. Our skilful opticians have long since produced low powers which answer all the purposes for which they were designed, but it remained for them to devise very high powers free from the practical objections that were inseparable from all the older forms. Great success was achieved by Messrs. Powell and Lealand with their $\frac{1}{25}$th, and now Messrs. Smith, Beck, and Beck have come into the field with a glass that leaves nothing to be desired either for facility of manipulation, abundance of light, or completeness of correction.

When we received their new $\frac{1}{20}$ th we took it out of its case with the expectation of finding a fine piece of optical workmanship, but anticipating a fastidiousness in its requirements that would limit its use. We first tried it upon a Podura scale, which is a more difficult test of accurate correction than any diatom. With the first, second, and third eye-piece of Messrs. Smith and Beck's series — giving powers of 1000 to 3000 linear—we obtained admirable definition with surprisingly little trouble. Then we tried it on the *Pleurosigma angulatum*, and were much gratified with the clear sharp rendering of its delicate markings, and the absence of colour or cloudiness at the edges of the valves. These trials left no doubt that the glass was a very fine one, but we still demanded *more*, and decided not to say over much in its favour, unless it would do good service with the rougher work which natural history or physiological pursuits require. We may seem exacting, but we demanded, first, that the new objective should work through a covering glass sufficiently thick to bear tolerably rough handling, and give any object a good squeeze without risk of fracture, and we further asked that the penetrating power of the glass should be sufficient that the slight inequalities inseparable from living specimens, or hastily prepared objects, should not be a bar to its use. To test the new $\frac{1}{20}$th in these particulars we took a little piece of growing vegetation out of a marine aquarium, placed it on a slide, and covered it over with a glass square, seven-eighths of an inch each way, and much thicker than those used for delicate diatom slides. To our delight the new objective worked admirably under these conditions, and with a very moderate allowance of light, for it was half-past six o'clock on a rainy day, and no artificial illumination was employed. Our capture from the aquarium comprehended a variety of matters. Here was a tangled mass of the exquisite *spirulina;* there, single threads of the same beautiful plant, looking like small cables, and waving about with the singular

motion that gives so much interest to its tribe, and in one spot were five of the same delicate filaments united in a living plait. In this place was that busy rotifer, the *monura*, working his curious pick-axe, and exhibiting his internal organization in the most admirable way; in that place an *anguillula* writhed and twisted like a little *boa constrictor*, with his annulate structure strikingly defined, and his intestinal machinery exquisitely displayed. The scene was wonderful, and the glass used with the facility of a low power. This, we confess, astonished and delighted us. We saw that working naturalists could be supplied with a valuable instrument of research, which would advance their every-day labours, and not be reserved for some extraordinary specialty that would seldom occur. For rotifers, infusoria, desmids, and diatoms, the new glass possesses great advantages, and when we tried it upon the cell rotation in the anacharis, the delicate ripples of the proto-plasmic currents were readily displayed.

The construction of the new $\frac{1}{20}$th, although not copied from it, may be said to follow the plan introduced into this country by Mr. Wenham, namely, the employment of a single lens in front. This plan, which appears to us to resemble that long used in the telescopes, is called *dialytes*. It admits of large angle of aperture, perfect correction, flatness of field, and the capacity for working through glass twice as thick as the $\frac{1}{12}$th or $\frac{1}{16}$th required a few years ago. That these advantages will be highly appreciated by the scientific world we cannot doubt, and to Messrs. Smith, Beck, and Beck belongs the great merit of producing on a new pattern a very high objective that can be used with facility, and is free from the disadvantages and limitations to which very much lower powers were recently subject. We should add that the angular aperture of the new glass is 150°.

PROCEEDINGS OF LEARNED SOCIETIES.

BY W. B. TEGETMEIER.

GEOLOGICAL SOCIETY OF LONDON.

On Recent Changes in the Delta of the Ganges. By James Fergusson, Esq.—The author first explained the laws that govern the oscillations in rivers, either laterally or in the direction of their course; secondly, the causes operating to raise the banks, when flowing through flat plains, above the level of the country; and lastly, the immense relative thickness of the early deposits in deltas

over those of later periods, when the conditions of the river had come more nearly *in æquilibrium*. Mr. Fergusson then proceeded to point out that in historical times the Brahmapootra and Ganges, on entering the plains of Bengal—passing Goalparah and Rajmahal respectively—ran originally to the sea in a nearly due north and south course, parallel to one another. This symmetry was first disturbed by the upheaval of the Modopore jungle, north of Dacca, by which the Brahmapootra was diverted in a south-eastern direction into the depression known as the Sylhet Jheels, which were the result of the upheaval just described. He then further explained how the river, having filled up these Jheels, had returned to its former bed within the limits of the present century.

The paper then described the effect this change had already produced in reopening the rivers of the western half of the Delta, and showed that, if it were maintained, it would have the effect of so raising the eastern half as to restore the course of the two great rivers very nearly to the position they occupied before the disturbance above alluded to. The gradual retrocession of all the mouths of the tributaries of the Ganges, in consequence of the tilting back of the plain, by the gradual rise of the Deltaic plains, was adverted to.

Mr. Fergusson stated that he conceived we had sufficient historical indications to show that within the last 5000 years the plain of Bengal has been nearly in the same condition that the valley at Assam now is—a jungly swamp, with only a few inhabitable spots here and there on the banks of the larger rivers.

The last phenomenon alluded to was the "Swatch of low ground" in the Bay of Bengal. This was ascribed to the action of the tides, which, being accelerated on either shore of the bay, acquired a rotatory motion at the sand-heads, and, meeting in the centre of the bay, scooped or swept out this depression in the centre, and by this action prevented the growth of the Delta seaward to the extent that would otherwise take place.

On the Origin and Subsequent Alteration of Mica-schist.—Mr. H. C. Sorby read a paper on this subject, in which he stated that when ripples are formed whilst material is being deposited, a structure is generated which is termed "ripple-drift." This structure may frequently be seen in polished sections of clay-slates, and also, in a form modified through metamorphism, in many mica-schists. From a consideration of the facts revealed by an examination of those rocks, the author concluded that mica-schist is of sedimentary origin, metamorphosed after deposition, and sometimes after the production of cleavage and other physical changes, and that the bands of different minerals represent the planes of original deposition.

ROYAL INSTITUTION.—*May* 8.

On the Soils of England.—In his lecture "On the Capabilities of the Soils of England," Professor Voelcker advocated several

views opposed to the general belief of agriculturists. He stated that the fertility of land was not capable of being permanently decreased by bad management, whereas by good management the poorest land may be made to yield large and remunerative crops, as evidenced by the success of Flemish agriculture. Formerly the influence of the mechanical properties of the soil were much overrated, and at the present time too much influence is ascribed to the chemical properties. When potash or ammonia salts pass through soils the basic portion is retained, the acids passing away in conjunction with the lime of the soil. Soda, which is of less importance to plants, is not retained, whereas potash and ammonia are absorbed both by clay or silicate of alumina, and by hydrated oxide of iron, and retained in spite of repeated washings. The sesquioxides, of which those of Iron ($Fe^2 O^3$) and Aluminium ($Al^2 O^3$) are taken as types, may be regarded as weak acids, retaining the alkalies in the soil. Professor Voelcker mentioned that so far from the soil of England being in the process of exhaustion, that its fertility was being greatly augmented, in good farm practice the restoration being in advance of the exhaustion. As a proof of this he stated that in Norfolk the average produce of wheat was—

In 1773 = 15 bushels per acre.
In 1796 = 28 bushels per acre.
In 1862 = 32 to 36 bushels per acre.

The increase being due to drainage, tillage, and to the growth of improved varieties.

ZOOLOGICAL SOCIETY.—*May* 14.

Mr. Reade on the Habits of the Gorilla.—Mr. W. Reade, who has been travelling for some months in the gorilla country, near the Gaboon, on the western coast of Africa, read a paper on the habits of this animal. He stated that it was so extremely shy that it was most difficult to get sight of, that its mode of progression was on all fours, and that its attacking the hunters by advancing in the erect posture and beating its breast, was entirely imaginative. When wounded the gorilla will attack the hunters in self-defence, Mr. Reade meeting one man whose wrist had been injured by a gorilla that bit him, and then escaped. Mr. Reade secured the services of the hunters employed by M. Du Chaillu, and they asked him if he wished to buy gorilla skins, as M. Du Chaillu did. They stated that during their recollection no man had ever been killed by a gorilla, and that the ordinary leopard was a much more dangerous animal to its pursuers. The hunters spoke in great terms of affection respecting M. Du Chaillu, but they asserted that he never shot a gorilla. Mr. Reade stated that the animal when captured young was capable of being tamed, and became very docile.

NOTES AND MEMORANDA.

INOCULATION FOR PLEUROPNEUMONIA.—M. C. Lenglen describes to the French Academy the success of inoculation as a preservative against the above disease. In the first place he obtained the virus from the lung of an ox that was affected; but subsequently he obtained the matter in a milder form from the tails of the inoculated animals, portions of which became diseased, and were cut off by the operator. At the time of writing his paper he was employing virus which had passed through twenty-five individuals.

THE SLEEP OF CHLOROFORM AND COMA.—M. Flourens contrasts the sleep produced by chloroform with the coma that results from the inflammation called *meningitis*. In coma he says an animal does not sleep; it has its eyes habitually closed, but opens them on the slightest inducement. In a natural state the pulse of a dog is from 100 to 120 a minute, and respiration from 20 to 30. In coma its pulsations are only from 80 to 90, and its respirations 24. Chloroform produces real sleep, with suspension of sensibility; the pulsations (of a dog) are 60, and the respirations 16. After the death of an animal from coma, the brain is covered with red spots, and its vessels congested with blood. An animal killed by prolonged use of chloroform does not exhibit these red spots, only the vessels of the *dura mater*, and particularly those of the cranium, are injected. Thus in the first case congestion is *intra* cerebral, and *extra* cerebral in the last.—*Comptes Rendus.*

SUN SPOTS AND AURORAS.—*Comptes Rendus* contains a letter from M. R. Wolf to M. Eliede Remmont, in which the former says, "I find, in accordance with M. Fritz, that the frequency of solar spots corresponds exactly with that of auroras, so that we observe in the latter both the period of $11\frac{1}{9}$ years and the great period of 56 years, the existence of which I have demonstrated for solar spots."

SQUARING THE CIRCLE.—M. Robinet presented to the French Academy a series of equations laboriously worked out and represented as having a remarkable approximation to accuracy. The proportion of various multiples and fractions of the diameter to the circumference is given, and it is stated that "the side of a square equivalent to a circle of a diameter equal to unity $= \frac{4}{16}\frac{8}{7} - 0{,}000{,}0006 = 0{,}8862269$."

CAUSES OF FERMENTATION AND PUTREFACTION.—M. Pasteur, many of whose researches will be found in our former numbers, has communicated to the French Academy the results of researches into the action attributed to the atmosphere of oxydizing, and thus consuming dead organic matter, a process which he finds to depend upon the growth of infusoria. He says, "Dead matter which ferments or putrefies does not then yield, solely at least, to forces purely physical or chemical. We must banish from science those preconceived views which consisted in the supposition that a whole class of organic substances—the nitrogenous—could acquire, by the hypothetical influence of direct oxydation, an occult force characterized by an internal movement, ready to communicate itself to organic substances pretended to be slightly stable." He then cites various experiments, and observes that "the slow combustion of organic matter after death, though real, is scarcely perceptible if the air is deprived of the germs of the lower organisms. It becomes rapid if the organic matter is permitted to cover itself with moulds, mildews, bacteriums, and monads. . . . The intermediate principles of organized beings would be, in some sort, indestructible, if we were able to suppress altogether those beings which God has made so extremely small, so useless in appearance, and life would become impossible, because the return to the atmosphere and to the mineral kingdom of that which had ceased to live would be entirely suspended."

SECCHI ON THE COMPANIONS OF SIRIUS.—M. Secchi, taking advantage of some fine weather in February, states that he succeeded in seeing the satellite of Sirius, but its distance was a little doubtful, probably 7·5″, angle of position 89°*.

* The diagram given by Mr. Webb in vol. i., p. 147, explains what is meant by angle of position.

With reference to the other luminous points he asks, "Are they realities or illusions?" One he noticed at 5″ distance, and about 180° angle of position. He says he mentions these observations to show the goodness of the telescope; but M. Goldschmidt's observations show that a much smaller instrument will suffice when the air is favourable.

Dr. Wallich on Pleurosigma Markings.—Dr. Wallich resumes this subject in the *Annals of Natural History*, with additional evidence of the correctness of his views. Operating upon a large *P. formosum*, he finds "the lozenge-shaped character of the interspaces unmistakably determined," and also the angulated structure of the elevations. We have seen one of Dr. Wallich's specimens under a $\frac{1}{25}$th objective shown so plainly as to leave little room for doubt. With a smaller specimen of *P. formosum*, and a $\frac{1}{8}$th with a high eye-piece, we have obtained a similar result. All species, however, may not have the same formation.

Dissociation of Carbonic Acid.—M. St. Claire Deville, whose experiments on the dissociation of water were explained in our April No., has in like manner resolved carbonic acid into an explosive mixture of oxygen and carbonic oxyde, in which some nitrogen was present. The temperature at which the dissociation was effected was about 1300° C. The presence of the nitrogen was of course accidental.

Formation of Hail.—M. Sanna-Solaro contests the idea that hailstones are formed by successive concretions. On the contrary, he affirms the congelation to begin from without, and the so-called nucleus to be the result of pressure. He says that when the external surface begins to freeze, the air-bubbles are driven towards the centre, and give rise to a pressure under which the crust yields. "The shock determines the congelation of a fresh layer, which is formed of two distinct parts, one deprived of air and transparent, the other opaque, in consequence of its included air-bubbles." This phenomenon is reproduced at each successive congelation, and if the hailstones reach the ground before the congelation is complete, their central portion may contain bubbles of air, water, and crystals of ice. Pyramidal stones he ascribes to the action of violent congelation, which causes the contained fluid to split the crust. He states that he has imitated hailstones by freezing water in transparent envelopes of caoutchouc. He likewise adduces reasons to show that hailstones are formed instantaneously. Further details will be found in *Comptes Rendus*, 27th April, 1863.

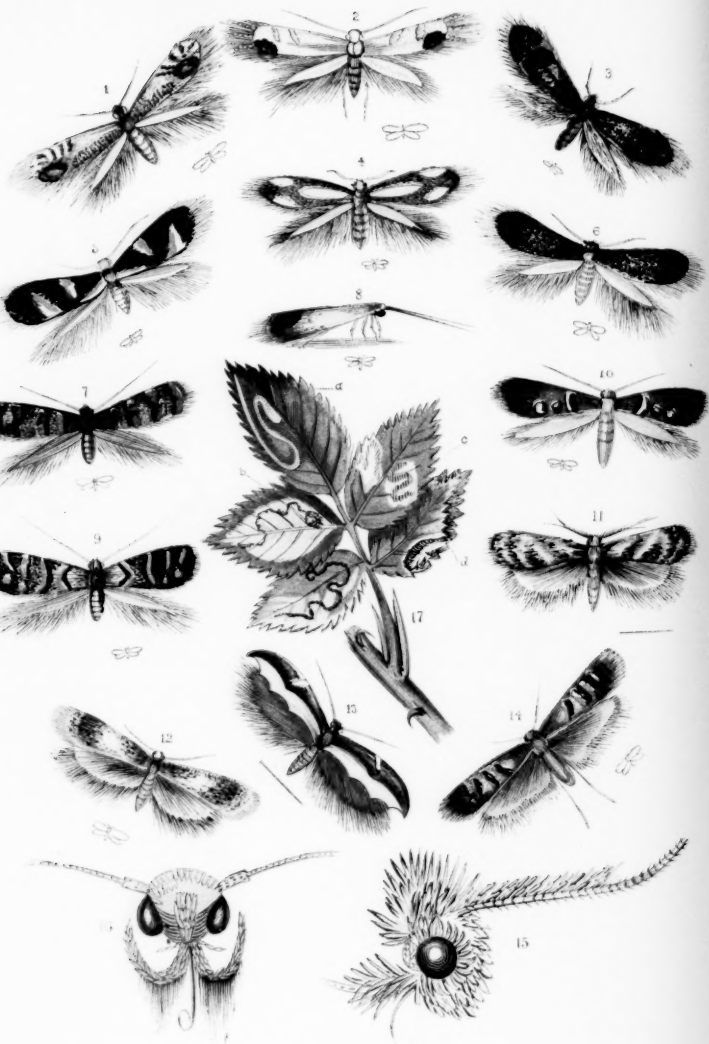
Island in Mars.—Mr. Nasmyth has discovered a little island in a supposed sea in Mars.

Gamma Libræ, a Double Star.—M. Goldschmidt finds a small companion about 20″ distant, and with an angle of position 153°. There is another and larger star more to the south of Gamma, 79″ distant, angle of position, 173°. He says the little star is easily seen by hiding the large one, and he thinks the two will be found members of a binary system.

The Fossil Human Jaw.—M. Quatrefages adheres strongly to the authenticity of a human jaw, alleged by certain workmen to have been taken from a deposit of black sand of an argillaceous and ferruginous character, resting upon the chalk near Abbeville, and covered by four superincumbent strata. The fact of a handsome reward having been offered for human remains, and certain appearances in the jaw itself, have induced strong doubts as to the genuineness of this fossil. If, however, it should be accepted, it would show that the pre-historic race to which it belonged were members of the orthognathous, or perpendicular-faced type, and not of the prognathous, or "snouty" variety of man. The dispute concerning this jaw does not affect any material point concerning the antiquity of man, and no geologist doubts that human remains will be found sooner or later in the Abbeville beds.

The Source of the Nile.—Sir Roderick Murchison has received a letter with the gratifying intelligence that Consul Petherick is not dead, as was reported, but has succeeded in joining Captains Speke and Grant. Captain Speke announces the great lake, Victoria Nyanza, as the main source of the Nile.

XUM



MICRO-LEPIDOPTERA,

(Leaf-Miners.)

1.—Cemiostoma scitella. *Hawthorn and Pear.*
2.—Cemiostoma laburnella. *Laburnum.*
3.—Nepticula aurella. *Blackberry.*
4.—Nepticula trimaculella. *Poplar.*
5.—Nepticula Subbimaculella. *Oak.*
6.—Nepticula Anomalella. *Rose-leaf.*
7.—Lithocolletis stettinensis. *Alder.*
8.—Tischeria marginea. *Bramble.*
9.—Glyphipteryx equitella. *Stonecrop.*
10.—Elachista luticomella. *Dactylis glomerata.*
11.—Ochsenheimeria. *Dactylis glomerata.*
12.—Gelechia Malvella. *Hollyhock.*
13.—Cerostoma Xylostella. *Honeysuckle.*
14.—Gelechia Hermanella. *Chenopodium.*
15.—Head of Ochsenheimeria.
16.—Coriscium. *Oak.*

All these figures are highly magnified. *The natural size is given in the lines beneath each, or in a minute figure.*

17.—Examples of different larva mines. *a*, mine of Nepticula aurella on the *Bramble*. *b*, mine of the Nepticula anomalella on the *Rose-leaves*. *c*, mine of Nepticula viscerella on the *Elm*. *d*, mine of Nepticula marginicolella on the *Elm*.